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QUICK REACTION EVALUATIONS OF MATERIALS AND PROCESSES

Delivery Order 0005: Effects of Several Paint Removal Technologies on the Static and Fatigue Properties of Thin Aerospace Structural Materials

John J. Ruschau and Patricia Youngerman

University of Dayton Research Institute

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Final Report

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14. ABSTRACT
An evaluation was conducted to ascertain the influence of paint removal technologies designed for use on thin skin aerospace structures, as well as to provide a sound database for future comparisons of other new and existing paint strip technologies. Materials evaluated were 2024-T3 sheet, both bare and clad, 7075-T6 sheet, thin skin aluminum honeycomb panels, and to a limited extent, polymeric composite sheet. The paint removal technologies examined include a CO_2 laser, chemical, plastic media blast (PMB), and conventional hand sanding. In order to properly compare the influence of these paint removal procedures on mechanical properties, comparisons were made to both as-received materials and similar samples that while not painted were subjected to the same thermal aging cycles as the painted samples. Types of tests performed were tensile and fatigue for the aluminum sheets materials, peel and flatwise tension for the honeycomb panels, and flexural and in-plane shear for the Gr-Ep composites. Results of all properties were statistically compared to ascertain significant differences in properties following the stripping operations.

15. SUBJECT TERMS
CO_2 laser, aluminum, sheet, honeycomb, chemical, PMB, fatigue, tensile, peel, flatwise tension, Gr-Ep, depaint

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PREFACE

This technical effort was originally initiated in June, 2007 on Air Force Contract F33615-03-D-5607, entitled, "Effects of Paint Stripping on Material Properties." Additional technical efforts were completed in July, 2009 under contract FA8650-09-D-5600. The work was administered by the Air Force Research Laboratory, Materials and Manufacturing Directorate, Systems Support Division, Wright-Patterson AFB, OH.

This work was conducted by the University of Dayton Research Institute under the supervision of Mr. John Ruschau, Program Manager. Other researchers who made major contributions to the success of this program include Ms. Patricia Youngerman, also of UDRI, who performed all of the fatigue evaluations and statistical analysis. Special thanks are given also to Mr. Donald Woleslagle and Dayle Pearson of UDRI who performed a significant portion of the mechanical tests and data reduction. Finally, Ms. Lou Cooper of UDRI was responsible for the organization and final preparation of this summary report. This report was submitted by the authors in October 2009. The contractor's report number is UDR-TR-2009-170.

1. INTRODUCTION

One of the major drivers in maintenance costs of United States Air Force (USAF) systems is associated with the continual paint/de-painting operations that all aircraft undergo over their useful life. Besides the obvious labor costs associated with removing the existing coating systems and the lost time while the aircraft is inoperable, the environmental costs involved with the disposal of the various toxic materials from de-painting operations are a major factor. In recent years the USAF has invested heavily in developing technologies that effectively remove the tough coating systems with minimal environmental waste. An example of one such technology is laser depainting [1-3] which has shown to be an effective means for removing a variety of organic-based coating systems with minimal hazardous waste. However, such technologies are only effective if they are proven to have no deleterious effect on the thin metallic and polymeric structures common to all aircraft.

To address these concerns, a program was undertaken to evaluate both currently used methods such as chemical strippers, plastic media blast (PMB), and hand sanding methods along with the newer de-painting technologies based on laser technology, to develop testing protocols and a valid database for commonly used thin aerospace materials such as aluminum and composite sheet materials, as well as honeycomb structures. This report is intended to serve as a repository for such data for use in future depainting evaluations.

2. TEST MATERIALS AND PROCEDURES

2.1 MATERIALS

Several sheets of 0.025 inch thick aluminum, 2024-T3 clad and bare, and 7075-T6 bare, were provided by the Concurrent Technologies Corporation (CTC) as both baseline (uncoated) and stripped panels.

To evaluate the various de-painting technologies, a standard epoxy primer with polyurethane topcoat (Mil PRF-85285), was applied to all but the baseline aluminum sheet in a 0.010" nominal coating thickness. Up to four paint/de-paint cycles were evaluated. Prior to paint, all aluminum sheets underwent a standard chromate conversion coating, including the baseline samples. Following each coating application, the painted panels and a number of baseline (non-painted) sheets of each alloy were artificially aged at 150°F for 7 days. The purpose of subjecting uncoated panels to this bake cycle was to provide a better comparison of the various depaint procedures, as it was thought that the bake cycle applied to painted and stripped panels may alone influence mechanical properties, thereby leading to erroneous conclusions as to the effectiveness of a particular de-paint technology. To investigate this issue, similar baseline panels of each alloy which were not subjected to the bake cycles were also evaluated to examine the influence of the artificial aging cycle.

In addition to the aluminum sheets just described, aluminum honeycomb panels in a nominal ½-inch thickness were purchased by CTC from Aviation Equipment Inc, North Hollywood, CA, and provided for peel and flatwise tension evaluations following the paint/depaint operations. The intent of these tests was to see if the various depaint operations caused a debit in the bond (i.e., FM73M-060 film adhesive) between the face sheet and the 5052 aluminum core. Face sheets for the honeycomb panels were 2024-T3 clad in thicknesses of 0.010, 0.016 and 0.020 inches. Additional details of the honeycomb panels and configuration can be found in Ref. 4.

Finally, a limited number composite panels of Gr-Ep that underwent paint/depainting procedures to remove a organic-based specialty coating were furnished for comparison to previous data reported on baseline materials (Ref. 5). Two panel configurations were furnished: a 16-ply, quasi-isotropic lay-up $[(0/0/45/-45/0/45/-45/0)_s]$ for flexural testing; and a 4-ply, 0/90 lay-up for in-plane shear testing.

The depaint technologies evaluated in this effort were chemical, laser, plastic-media blast (PMB), and hand sanding. The chemical stripper evaluated was identified as Plane Naked®, an environmentally-friendly chemical stripper free of methylene chloride and other toxic materials and approved for USAF applications. Chemical stripping was performed by trained technicians from Tinker AFB (566 Aircraft Maintenance Group) following procedures outlined in T.O. 1-1-8, Section 2.7.

Laser stripping was performed using a 6kW, continuous wave CO_2 robotic laser installed at the Oklahoma City Air Logistics Center (OC-ALC) at Tinker AFB, OK. The

PMB used in this effort was Type V and performed by technicians from Tinker AFB (309 Aircraft Maintenance Group) following T.O. 1-1-8, Section 2.11.3.

Finally, panels were hand sanded by maintenance technicians at CTC, Johnstown, PA, using random orbital sanders with 240 grit sandpaper. Procedures outlined in T.O. 1-1-8, Section 2.10.4 were followed.

2.2 SPECIMENS

The tensile specimen geometry used in this evaluation for the aluminum sheet is shown in Figure 1, while smooth and notched (Kt=2.8) fatigue specimen configurations are illustrated in Figures 2 and 3, respectively. All test specimens were machined and tested in the longitudinal orientation of each furnished sheet.

To evaluate potential debits in peel strength between the face ply and core, climbing drum peel testing was performed on the specimen configuration illustrated in Figure 4. Similarly, flatwise tension specimens, 2 x 2 inches, were machined from each honeycomb material to assess bond strength between the facings and the aluminum core.

In-plane shear specimens, 1 inch wide by approximately 8 inches long, were machined from the 4-ply Gr-Ep panels that underwent depainting. Samples were oriented 45° to the 0° fiber direction as required for shear property determination. Flex specimens, 0.50 inches wide by 12 inches long, were machined from the 16-ply panels and oriented in the 0° fiber direction.
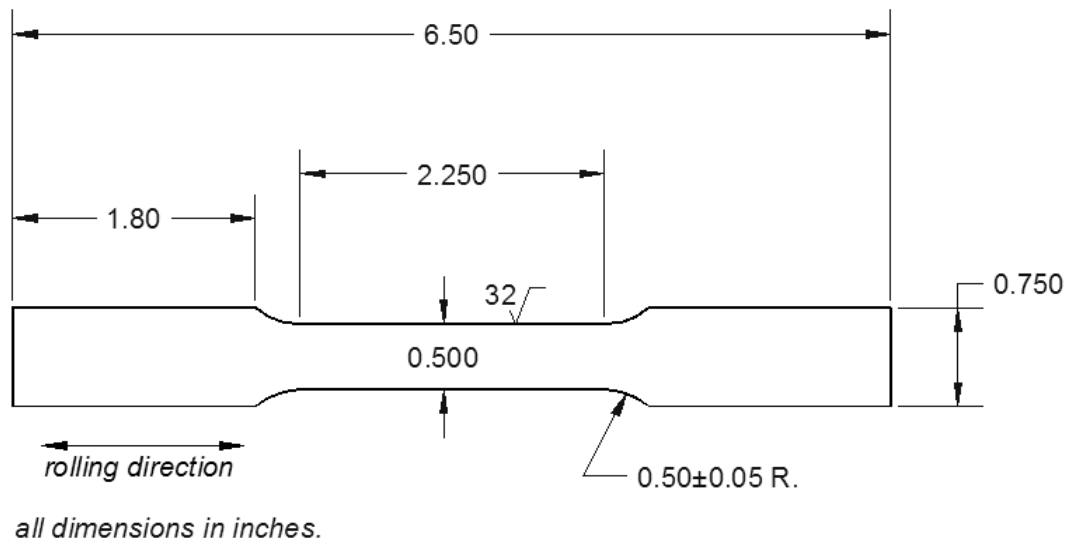
Figure 1. Tensile Specimen Geometry
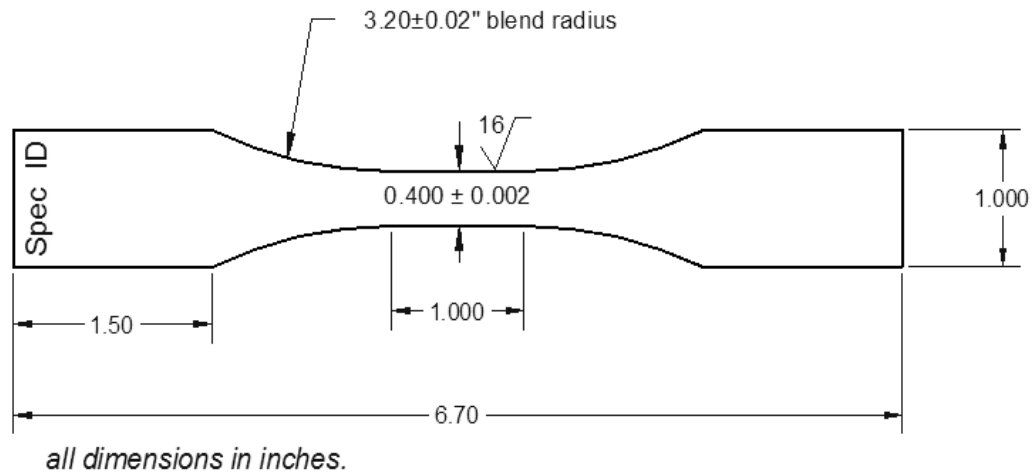
Figure 2. Smooth Fatigue Specimen Geometry (Kt=1.0)
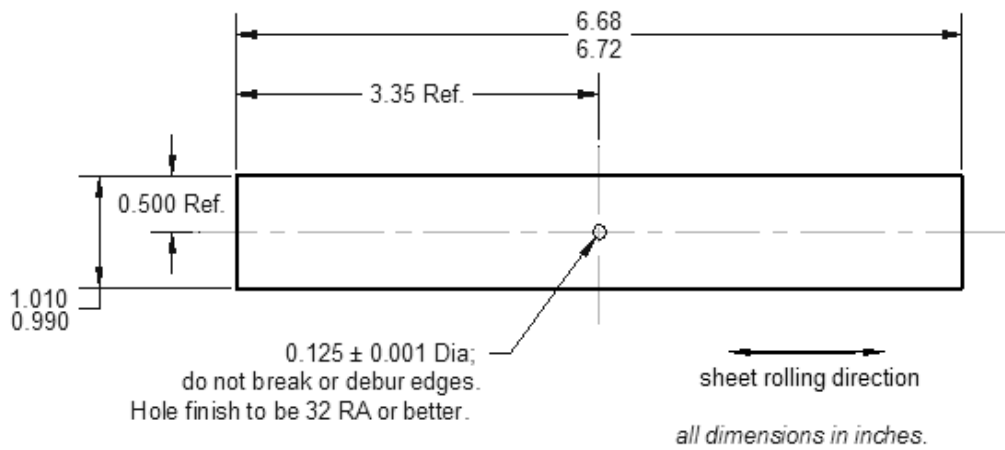
Figure 3. Notched Fatigue Specimen Geometry (Kt=2.8)

all dimensions in inches
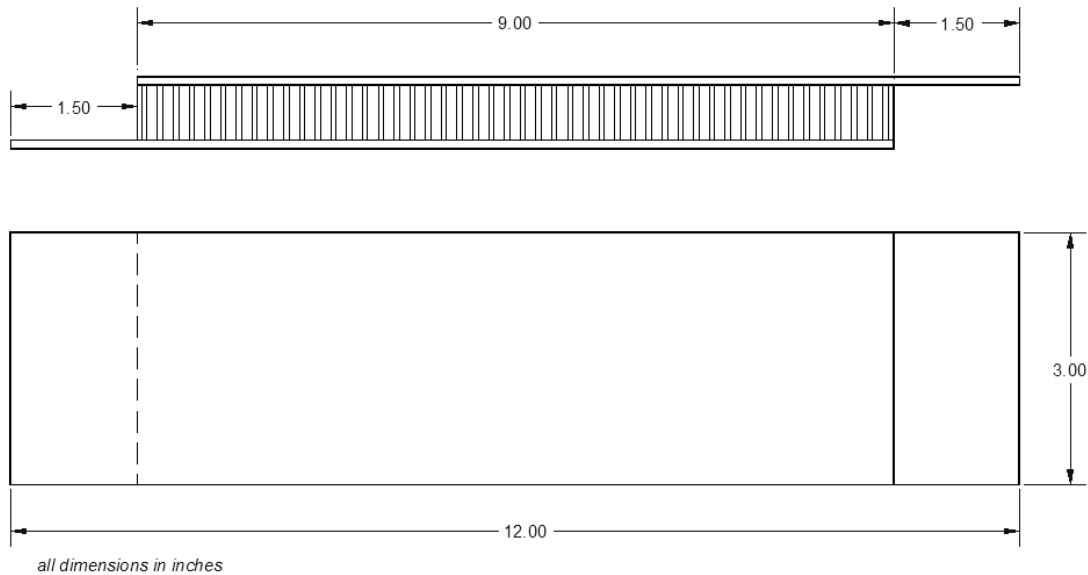
Figure 4. Climbing Drum Peel Specimen Geometry

2.3 PROCEDURES

Tensile testing was performed in an Instron 4505 universal test machine following guidelines outlined in ASTM E-8 *Tension Testing of Metallic Materials* [6]. All testing was done under displacement control at a rate of 0.1 inches/min. up to specimen failure. Specimen strain was obtained during test via an Instron 2-inch GL extensometer. Ductility, as measured as specimen elongation at failure, was measured after test using the fit-back method as described in the standard. A minimum of five tests were conducted per de-paint procedure per test panel for statistical comparisons.

Both smooth and notched fatigue testing was accomplished using an MTS servo-hydraulic test machine under lab air conditions following ASTM E466 *Conducting Force Controlled Constant Amplitude Axial Fatigue Tests of Metallic Materials* [7]. MTS model 647 wedge grips were used to grip the samples using a maximum grip pressure of 500 psi. Testing was performed under a sinusoidal load control mode at 30 Hz up to a maximum cycle count of 10,000,000. Alignment accuracy was verified at less than 4% prior to testing. The machined edges of all fatigue specimens were polished longitudinally via 600 grit polishing paper prior to testing to remove measurement and machining marks. No surface polishing was performed on either of the specimen surfaces (stripped or as-received) which might compromise the stripped finished surface and thus ensuing fatigue results. Initial testing of the 7075-T6 sheet samples resulted in occasional failures in the grip region, thereby invalidating fatigue results. Consequently it was necessary to adhesively bond polymeric tabs onto all the 7075 samples to eliminate grip failures.

Climbing drum peel testing on aluminum honeycomb panels was performed in an Instron 4505 universal test machine following ASTM 1781 *Climbing Drum Peel for Adhesives* [8]. As stated in the standard, this procedure is used to determine comparative measurements of adhesion between the skin sheet and honeycomb core and is particularly sensitive to surface preparation. The reasoning for this particular test was to determine of any of the depaint processes caused a debit in adhesion between said adherents. Peeling loads were digitally recorded during test to determine the average peel load, which in turn was used to calculate the average peel torque (in-lbf/in).

Flatwise tension testing was performed in an Instron 4505 test machine following procedures outlined in ASTM C297 *Flatwise Tensile Strength of Sandwich Constructions* [9]. Specimens were adhesively bonded to aluminum loading blocks using Hysol EA9359.3a, 2-part epoxy adhesive and cured at room temperature for 48 hours prior to testing. Aluminum loading blocks were prepared for adhesive bonding using a solvent degrease, grit-blast with 50 μm Al_2O_3 and treated using AC-130 sol-gel. Following each test, the failure modes were recorded and the sample remnants removed from the loading blocks by placing the failed samples in an oven at 400°C (752°F) for 48 hours. The loading blocks were then cleaned off with acetone and grit blasted for subsequent bonding. This process was repeated for flatwise tension samples representing each de-paint process.

In-plane shear testing was performed on the 4-ply Gr-Ep samples using an Instron 4507 universal test machine following guidelines in ASTM D3518 *Standard Test Method for In-Plane Shear Response of Polymer Matrix Composite Materials by Tensile Test of a ±45°Laminate* [10]. Biaxial strain gages (Micro-Measurement # CEA-00-125UT-350) were bonded to the non-stripped side for measurement of shear modulus. Testing was performed under displacement control at a rate on 0.05 in/min.

Finally, 4-point flex testing on samples removed from the 16-ply, quasi-isotropic Gr-Ep panels using guidelines established in ASTM D6274 *Flexural Properties of Unreinforced and Reinforced Plastics and Electrical Insulating Materials by Four-Point Bending* [11]. A span-to-depth ratio of 32:1 was employed for all tests, with the stripped side in compression. An Epsilon deflectometer was centered on the samples' mid-point in order to measure specimen deflection. Testing was performed under displacement control at a rate of approximately 1.0 in/min.

3. RESULTS AND DISCUSSION

3.1 ALUMINUM SHEET

3.1.1 Tensile

A summary of tensile results for baseline and stripped samples from both the 2024-T3 and 7075-T6 sheets is provided in Table 1. Individual sample results are furnished in Appendix A. In Table 1 the average strength properties that are statistically different than the unstripped baked results at a 90% confidence level are noted with a "✓" immediately next to the property of concern. Note that for the 2024 clad material, a single clad sheet panel was evaluated following 4 cycles of laser stripping only. As there was no baseline developed for clad 2024, no statistical comparison can be made following the laser depainting operation for this material and condition.

In addition to the tabulated summary, values of average yield strength (YS) and ultimate tensile strength (UTS) with error bars are illustrated in Figures 5 and 6 for the 2024-T3 YS and UTS, and Figures 7 and 8 for the 7075-T6 YS and UTS, respectively. Also presented in each plot is a line representing the appropriate MMPDS Handbook [12] value in terms of "A-allowables." Excluding the 2024 clad results, the plots in Figures 5 and 6 for the 2024-T3 material point out the highest average YS and UTS were achieved for the chemical 4 cycle group, with the lowest average strengths for the hand sanded group. Average YS and UTS results for the 2024 CO_2 and baked groups were identical, while the 4 cycle chemical and PMB results slightly higher that baseline (baked). The influence of the 4 bake cycles is seen as a slight decrease in average YS following the bake cycles, with little change noted in UTS following baking. A statistical decrease in both YS and UTS are seen following both the single chemical strip and the hand sanding operation. Finally, comparisons between the average results for the clad 2024 CO_2 group and the MMPDS "A allowables" for 2024 clad show that the average strength properties following CO_2 stripping to be well in excess of the design allowables.

Examination of the 7075 results in Table 1 and Figures 7 and 8 show little difference is strength properties for any of the stripped groups relative to the baked results. Average YS and UTS values were again generally highest for the chemical (4 cycle) group, with the single chemical strip group slightly lowest amongst the stripped results and virtually the same as the baked group. For the 7075 results, the effect of the four bake cycles is seen as causing a slight but statistical 'real' increase in both YS and UTS properties. Finally, all properties for all sample groups far exceeded the MMPDS "A-allowable" values listed for similar sheet material.

Table 1. Average Tensile Properties for Aluminum Sheet Following Various Depaint Operations

Alloy	Panel ID	Condition	# of Events	YS (ksi)	UTS (ksi)	Elong. (%)
2024-T3	Al-2b-BASELINE-1, -2	baseline, no bake	0	53.1	71.4	16.4%
2024-T3	Al-2b-BAKE-4, -5	baseline, baked	4	**52.7**	**71.5**	**17.0%**
2024-T3	Al-2b-STD-5, -6	CO_2 laser	4	52.7	71.5	16.9%
2024-T3, clad	Al-2c-STD-5 (clad)	CO_2 laser, clad	4	49.0 ✓	65.7 ✓	16.3% ✓
2024-T3	Al-2b-CHEM-2	chemical (1 cycle)	1	52.5 ✓	71.3 ✓	17.1%
2024-T3	Al-2b-CHEM-5	chemical (4 cycles)	4	53.9	72.8	16.8%
2024-T3	Al-2b-PMB-4, -5	PMB	4	53.4	72.4	17.2%
2024-T3	Al-2b-SAND-4, -5	hand sand	4	52.3 ✓	70.9 ✓	16.9%
7075-T6	Al-7b-BASELINE-1, -2	baseline, no bake	0	75.0 ✓	84.7 ✓	13.7%
7075-T6	Al-7b-BAKE-4, -5	baseline, baked	4	**75.7**	**85.0**	**12.7%**
7075-T6	Al-7b-STD-5, -6	CO_2 laser	4	76.0	84.9	12.9%
7075-T6	Al-7b-CHEM-2	chemical (1 cycle)	1	75.6	85.0	13.2%
7075-T6	Al-7b-CHEM-5	chemical (4 cycles)	4	77.2	85.4	11.7%
7075-T6	Al-7b-PMB-4, -5	PMB	4	76.7	85.5	13.7%
7075-T6	Al-7b-SAND-4, -5	hand sand	4	76.5	85.2	12.4%

✓ – *Denotes significant difference (90% CL) from baked data.*
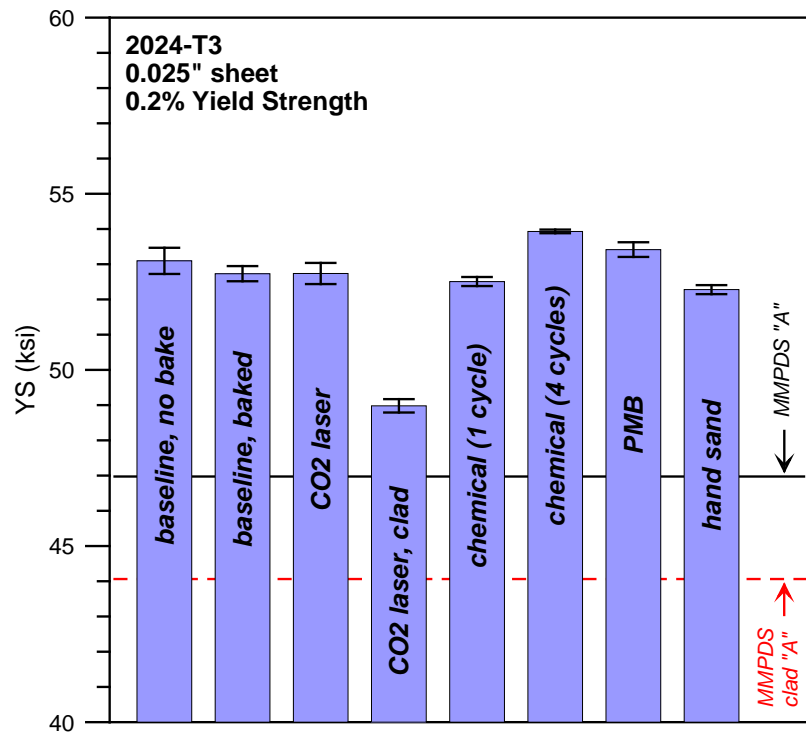
Figure 5. 2024-T3 YS Following Various Depaint Operations
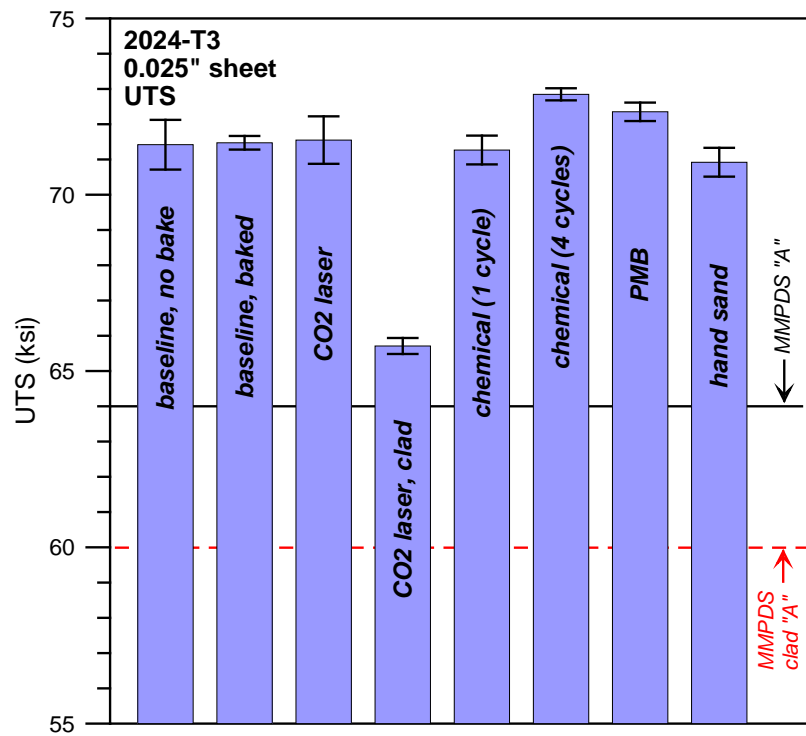
Figure 6. 2024-T3 UTS Following Various Depaint Operations
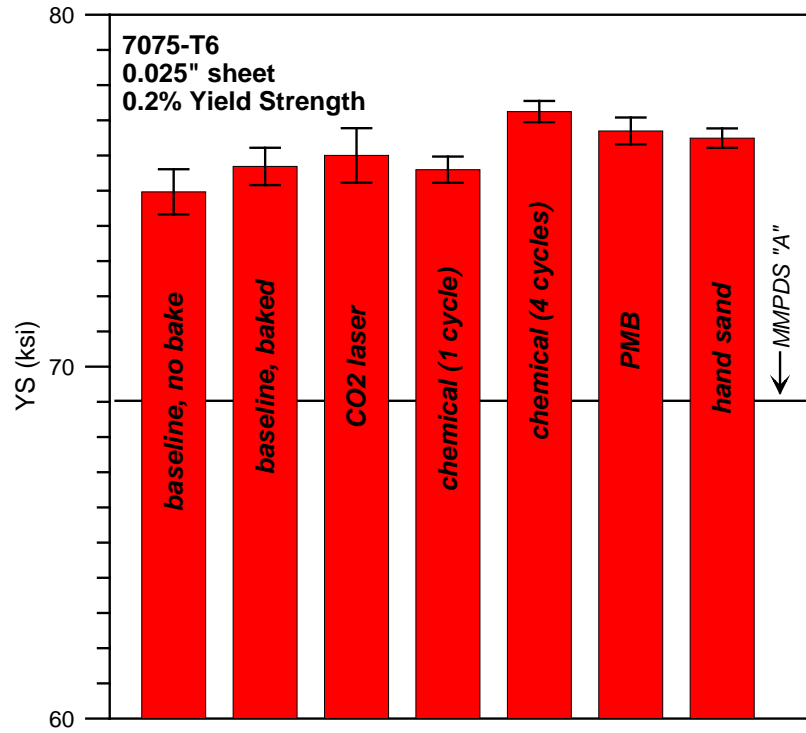
Figure 7. 7075-T6 YS Following Various Depaint Operations
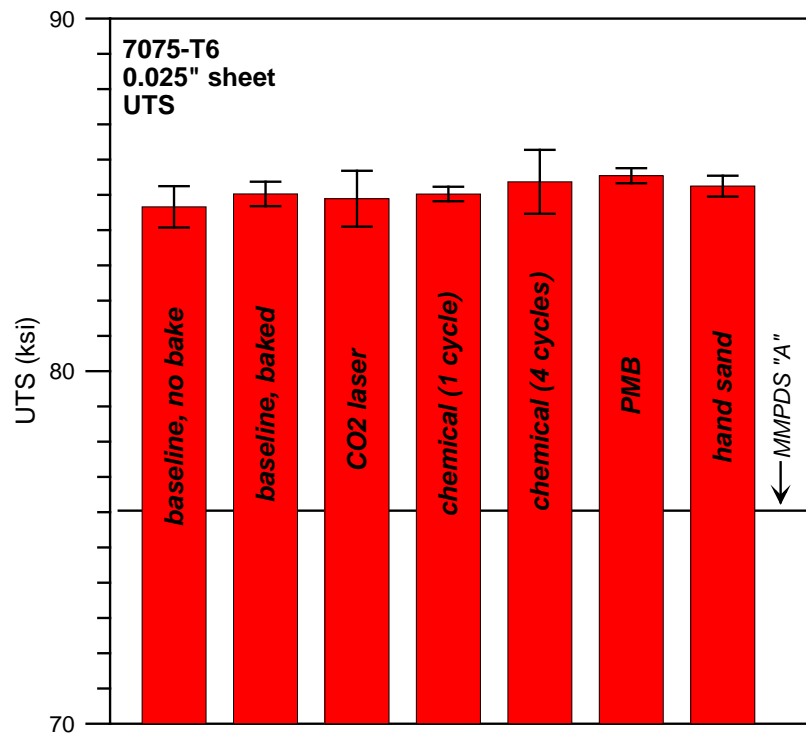
Figure 8. 7075-T6 UTS Following Various Depaint Operations

3.1.2 Fatigue

Baseline fatigue testing was first performed on baseline 2024 and 7075 sheet for both smooth and notched (Kt=2.8) to develop rudimentary S-N curves for each case. The resulting S-N curves are shown in Figure 9. The results for the 2024-T3 smooth and notched sample groups show minimal scatter and are in excellent agreement with published data (Ref. 6 and MMPDS) for the smooth fatigue configuration. On the other hand, results for the 7075 baseline groups show considerably more scatter, particularly at the lower stress, longer life conditions. The smooth 7075 fatigue data fall slightly below reference data from MMPDS throughout the range of stress levels examined.

From these data, two stress levels were chosen for each case to represent short and long life behavior. Replicate tests (minimum 5 each) were then run at each of the two stress levels for each depaint technology in order to provide some statistical comparison of failure life. The results of these replicate tests for 2024-T3 smooth and notched fatigue are shown in Tables 2 and 3, respectively, and as box plots in Figures 10 and 11. Average smooth fatigue life at the low stress, high cycle condition (e.g., 45 ksi, max) is greatest for the non-baked baseline group, with the remaining de-paint group results fairly similar, with the exception of the 4-chemical strip group and the clad laser-stripped results. Comparisons with the 4-baked group were made at a 90% confidence level. Those results are illustrated as a "✓" in the tables and figures when the assumption of equal means is violated (i.e., not from the same population). At the higher stress, lower life condition, the highest average life was seen with the 1-cycle chemical strip group, while the lowest average life was seen with the hand-sanded group (excluding the clad results). Statistical comparisons with the 4-baked results indicate that nearly all groups were significantly (90% CL) lower for all depaint groups, with the exception of the single chemical strip group which was the highest. Comparisons between the laser, chemical (4 event), and PMB, however, indicate that these three groups are similar to one another. Thus no depaint operation resulted in significantly lower properties, exception being the hand-sanded group which fell below the laser results for this particular test condition.

The 2024 notched fatigue results for the low stress, high cycle condition and shown both in Table 11 and Figure 11, indicate highest average fatigue life for the laser stripped group, followed then by the other depaint groups. In fact, the lowest average fatigue life (excluding the clad group) was the baked group. At the higher stress, low stress condition, only the 4-cycle chemical-strip and clad laser-stripped groups were statistically below the baked reference group results. Thus summarizing the 2024 fatigue results, there was no one group consistently inferior in fatigue performance to the baked, non-stripped results except for the clad results in all cases. However, for both of the smooth stress test conditions and one of the two notched conditions, the chemical 4-strip event group was statistically lower than the reference basked results. Scatter in results and the small population size (e.g., 5 typical) make more detailed comparisons difficult to perform.
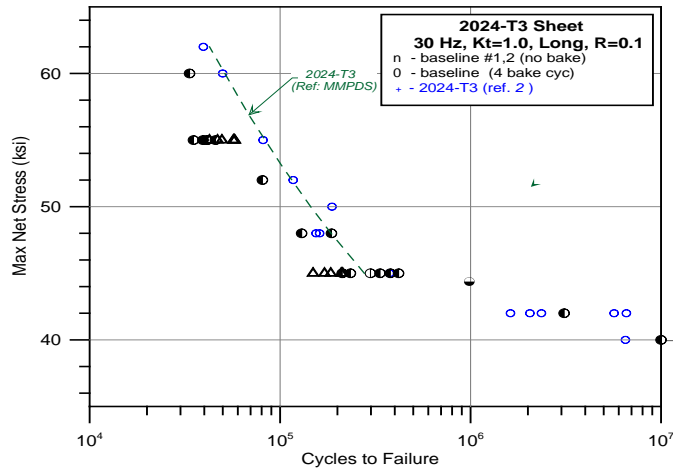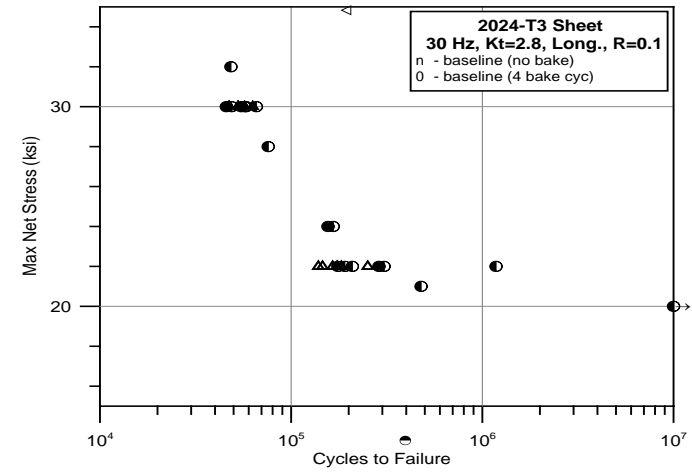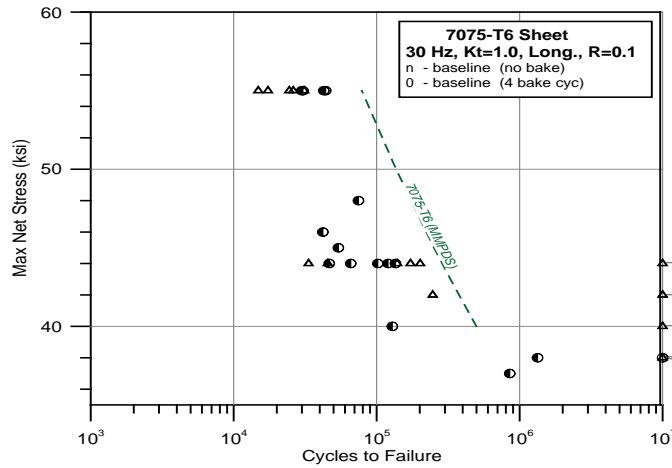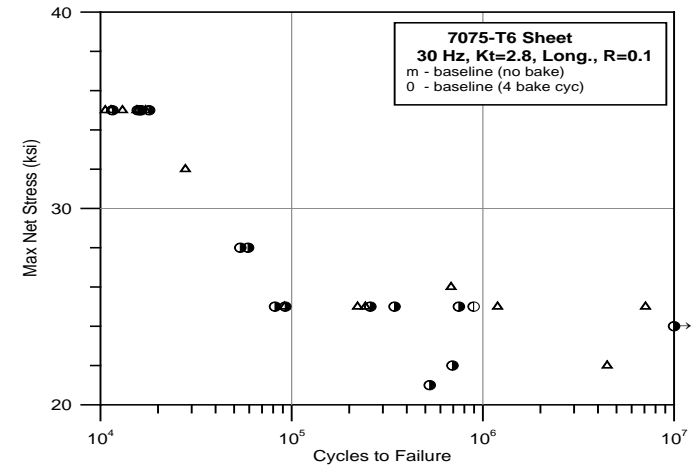
**Figure 9. Fatigue Data for Baseline 2024-T3
Smooth (a) and Notched (b), and 7075-T6 Smooth (c) and Notched (d) Configurations**

Table 2. Fatigue Results for 2024-T3 (Kt=1.0) Following Various Depaint Operations

Condition (# Events)	Max Net Stress (ksi)	Average Cyclic Life	Standard Deviation (Cycles)	Significant from Baked Group?
Baseline, no bake	45	312,743	80,991	✓
Baked (4)	**45**	**192,281**	**29,302**	
Laser Stripped(4)	45	166,619	66,596	
Chemical (1)	45	184,578	65,180	
Chemical (4)	45	145,148	46,176	✓
PMB (4)	45	205,528	46,037	
Sand (4)	45	217,667	42,155	
Clad, Laser (4)	45	96,760	15,735	✓
Baseline, no bake	55	40,562	3,866	✓
Baked (4)	**55**	52,628	6,231	
Laser Stripped(4)	55	40,305	5,326	✓
Chemical (1)	55	57,941	14,558	
Chemical (4)	55	39,096	13,349	✓
PMB (4)	45	46,832	6,129	✓
Sand (4)	45	37,330	19,610	✓
Clad, Laser (4)	55	28,790	6,734	✓

Table 3. Fatigue Results for 2024-T3 (Kt=2.8) Following Various Depaint Operations

Condition (# Events)	Max Net Stress (ksi)	Average Cyclic Life	Standard Deviation (Cycles)	Significant from Baked Group?
Baseline, no bake	22	391,448	389,529	✓
Baked (4)	**22**	**176,320**	**40,490**	
Laser Stripped(4)	22	1,911,478	2,377,490	✓
Chemical (1)	22	366,517	253,795	✓
Chemical (4)	22	259,785	129,401	
PMB (4)	22	367,535	399,121	✓
Sand (4)	22	236,797	58,083	
Clad, Laser (4)	22	148,048	9,888	✓
Baseline, no bake	30	55,073	7,104	
Baked (4)	**30**	**53,395**	**5,955**	
Laser Stripped(4)	30	53,460	3,820	
Chemical (1)	30	52,717	4,677	
Chemical (4)	30	47,800	5,022	✓
PMB (4)	30	54,675	6,978	
Sand (4)	30	61,109	14,834	
Clad, Laser (4)	30	42,375	4,943	✓

a. 2024 smooth (45 ksi max stress)

b. 2024 smooth (55 ksi max stress)
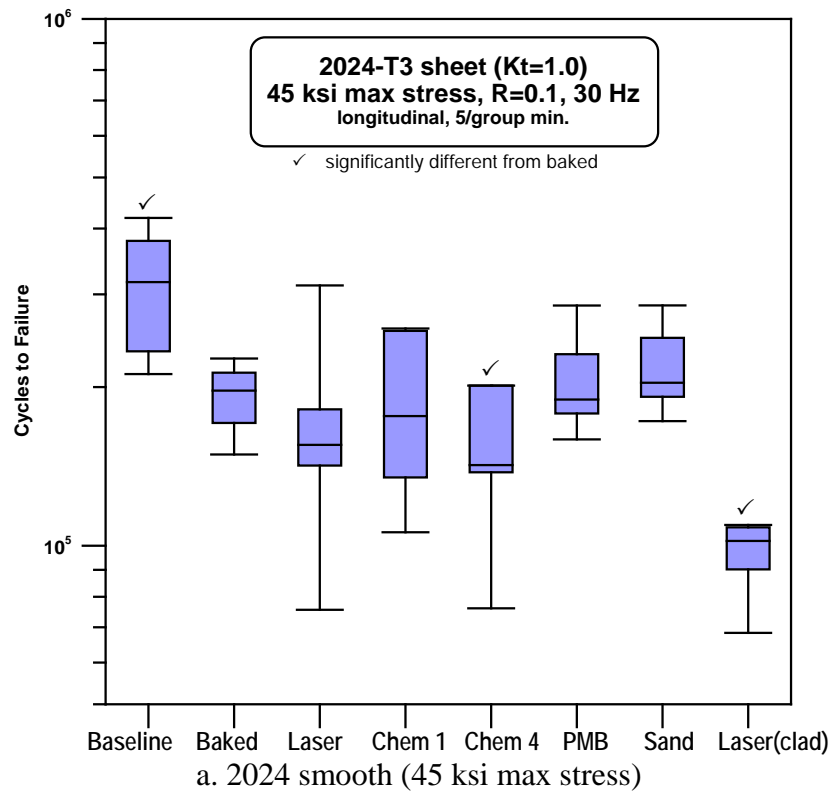
Figure 10. Smooth Fatigue Life Data for 2024-T3 Sheet Samples Following Various Depaint Operations

a. 2024 notched (22 ksi)

b. 2024 notched (30 ksi)
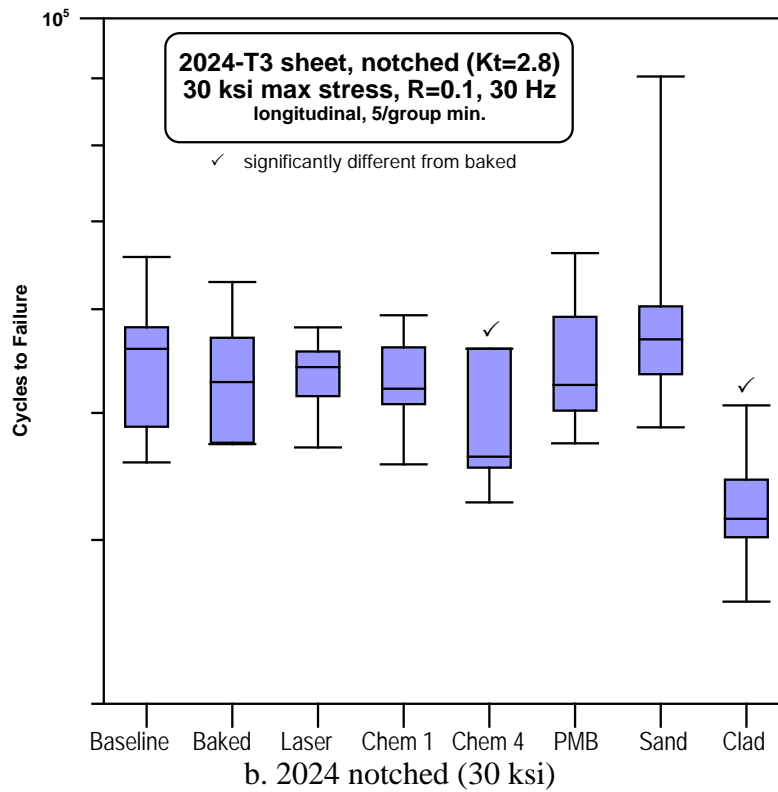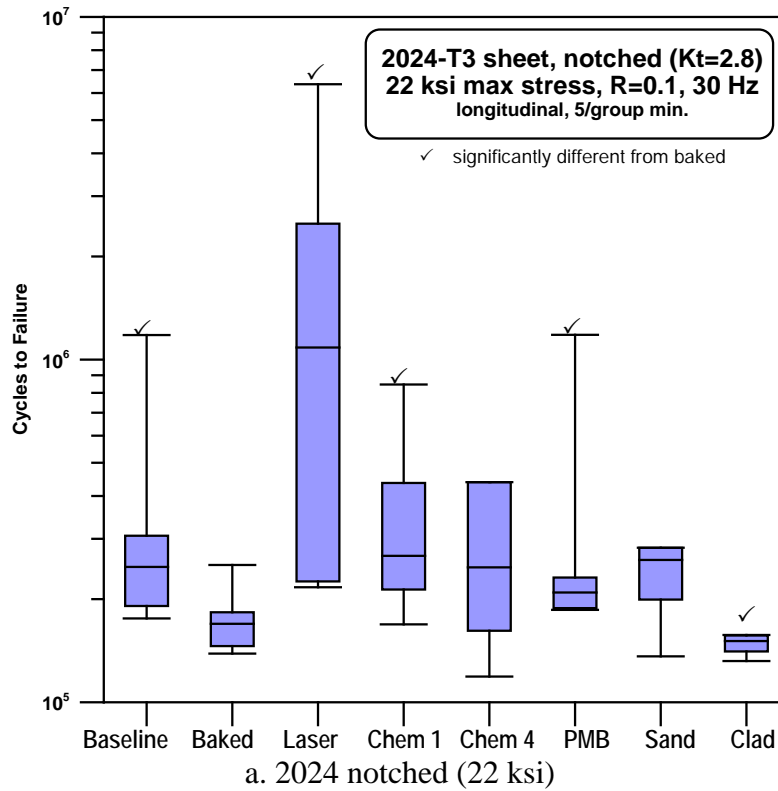
Figure 11. Notched Fatigue Life Data for 2024-T3 Sheet Samples Following Various Depaint Operations

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Results for the 7075 smooth and notched fatigue tests are tabulated in Tables 4 and 5, respectively. Similarly, box plots for the 7075 results are illustrated in Figures 12 and 13 for smooth and notched conditions, respectively, which show the relative ranking, scatter, and statistical comparisons between the various depaint procedures and the baked sample groups. From Figure 12, it can be seen that for the smooth ($Kt=1.0$) test condition, no statistically significant debit results from any of the depaint operations except for the chemical, 4 strip group. In fact for the higher stress case (Figure 12b) all sample groups are statistically higher than the baked group, again, exception with the exception of the 4 strip chemical group. This more than likely is the result of one or more low failures in the baked group which reduced the mean life for this group, as evident with the low scatter band.

For the notched fatigue case ($Kt =2.8$), scatter in fatigue life for the lower stress (25ksi, Figure 13a) was very high. At the higher stress, low life condition (Figure 13b), scatter is greatly reduced. In both cases, no statistical differences are noted in the mean fatigue life following the laser or single chemical strip event relative to the baked condition. For the lower stress condition (Figure 13a), a statistical decrease in average life was also seen following the chemical (4 event), PMB, and hand sanding depaint operations, though at the higher stress (13b), such debits were not seen.

Individual fatigue data is furnished in the Appendix for both sheet materials and stress concentration (Kt).

Table 4. Fatigue Results for 7075-T6 (Kt=1.0) Following Various Depaint Operations

Condition (# Events)	Max Net Stress (ksi)	Average Cyclic Life	Standard Deviation (Cycles)	Significant from Baked Group?
Baseline, no bake	44	93,904	37,053	
Baked (4)	**44**	118,372	75,445	
Laser Stripped(4)	44	133,809	71,236	
Chemical (1)	44	64,732	12,611	
Chemical (4)	44	30,006	9,008	✓
PMB (4)	44	110,569	25,809	
Sand (4)	44	90,254	15,821	
Baseline, no bake	55	36,764	7,604	✓
Baked (4)	**55**	**22,776**	**6,611**	
Laser Stripped(4)	55	32,421	7,127	✓
Chemical (1)	55	31,320	5,062	✓
Chemical (4)	55	10,875	3,880	✓
PMB (4)	55	41,126	6,152	✓
Sand (4)	55	33,470	8,204	✓

Table 5. Fatigue Results for 7075-T6 (Kt=2.8) Following Various Depaint Operations

Condition (# Events)	Max Net Stress (ksi)	Average Cyclic Life	Standard Deviation (Cycles)	Significant from Baked Group?
Baseline, no bake	25	334,363	332,336	
Baked (4)	**25**	**1,767,242**	**3,005,863**	
Laser Stripped(4)	25	817,032	1,313,903	
Chemical (1)	25	1,452,158	2,746,004	
Chemical (4)	25	104,014	39,121	✓
PMB (4)	25	76,610	18,254	✓
Sand (4)	25	61,497	7,793	✓
Baseline, no bake	35	15,523	2,383	
Baked (4)	**35**	**13,540**	**2,786**	
Laser Stripped(4)	35	14,339	1,246	
Chemical (1)	35	14,913	1,425	
Chemical (4)	35	20,365	5,033	✓
PMB (4)	35	15,498	1,876	
Sand (4)	35	15,717	3,826	

a. 7075 smooth (44 ksi max stress)

b. 7075 smooth (55 ksi max stress)
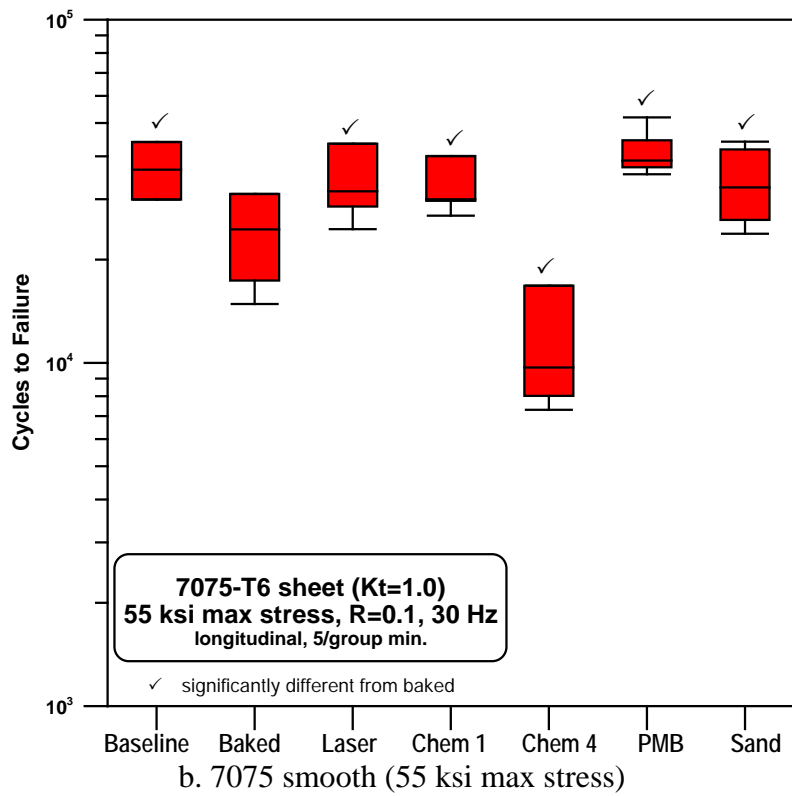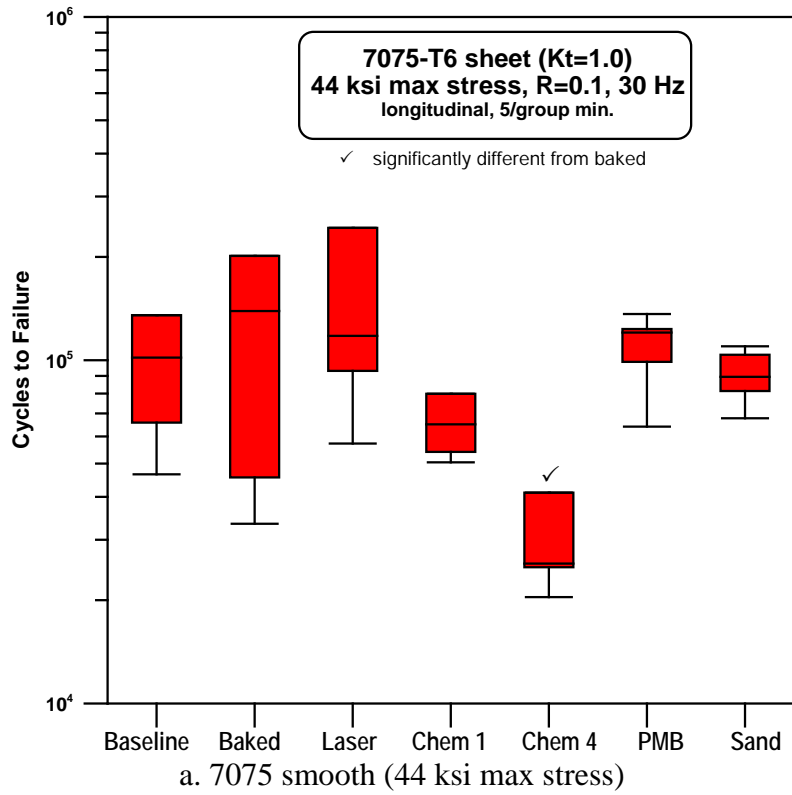
Figure 12. Smooth Fatigue Life Data for 7075-T6 Sheet Samples Following Various Depaint Operations

a. 7075 notched (25 ksi max stress)

b. 7075 notched (35 ksi max stress)
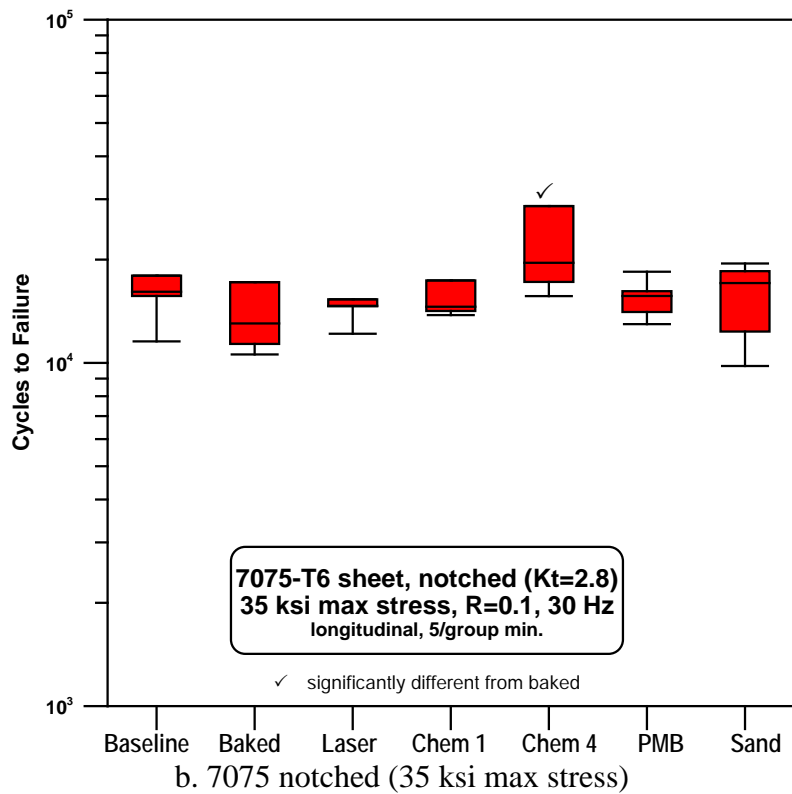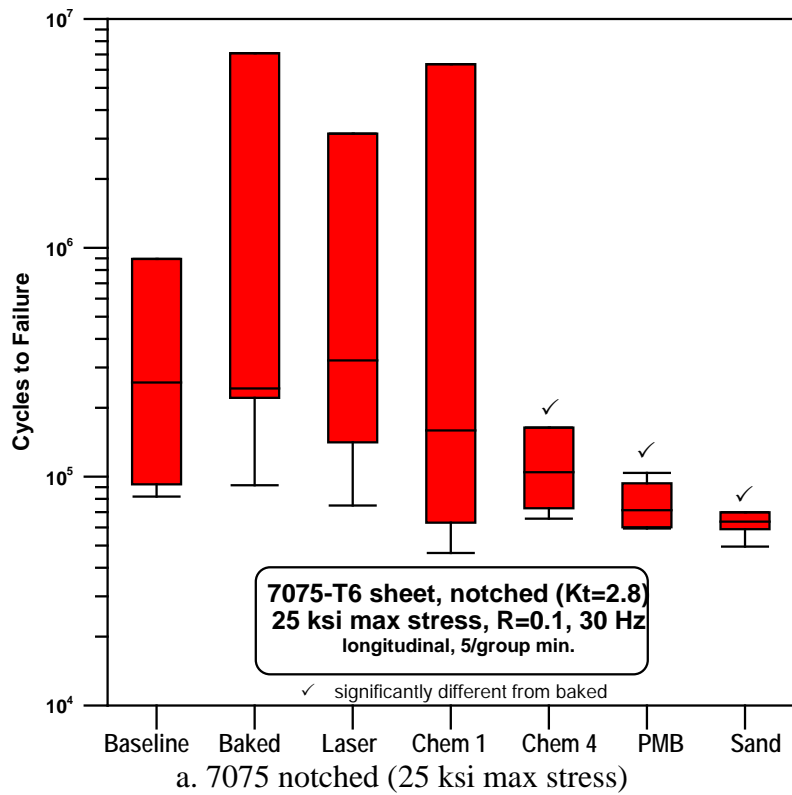
Figure 13. Notched Fatigue Life Data for 7075-T6 Sheet Samples Following Various Depaint Operations

3.2 ALUMINUM HONEYCOMB

The results for tests on aluminum honeycomb materials are described in detail in Reference 4 and are represented briefly in this section.

3.2.1 Climbing Drum Peel
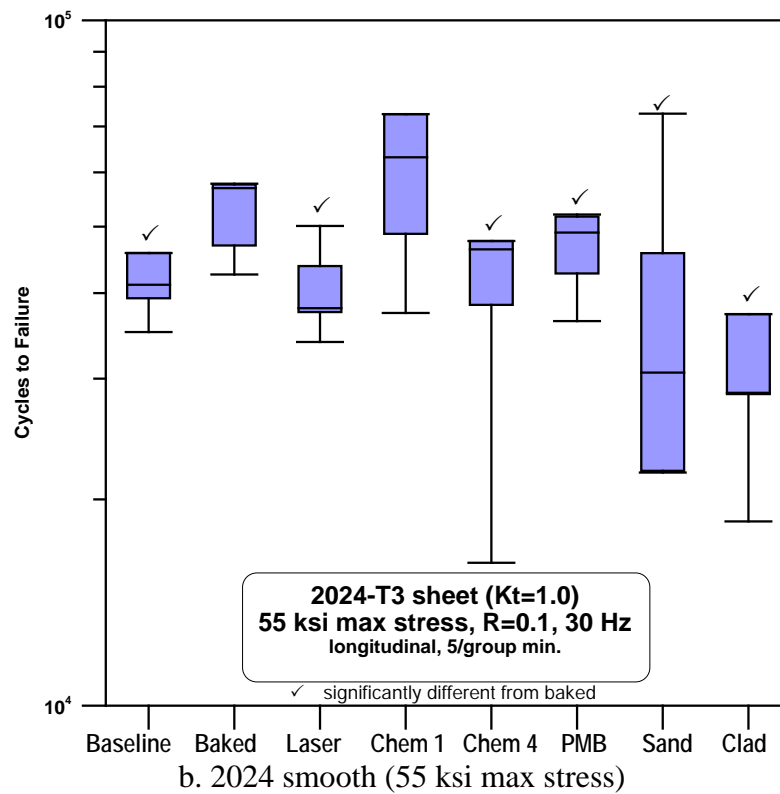
The results of peel tests performed are summarized in Table 6. Individual results are available in Ref. 4. All tests resulted in valid cohesive failures between the facings and honeycomb core. The average peel torque values listed in Table 6 indicate that for all panel sizes evaluated, the laser de-paint results were equal to or higher than the other sample groups. Likewise, the hand-sanded group averages were consistently lowest for all facing thicknesses. Average peel torque was consistently lowest for the 0.02 inch facing panels for all depaint groups, presumable a result of the larger core size.

In comparing the means at a 90% confidence level the sanded results were statistically lower than the laser results for all facing thickness, and lower than the baked condition for the two larger facing thicknesses. Statistical comparisons between the baseline and baked 0.010 inch results indicated that while the two groups were similar, the laser results were actually statistically higher than the baked results, indicating a slight increase in peel resistance following laser stripping for the thinnest facing panels. Similarly, for the 0.016 inch facing panels, the laser results were statistically higher than the baked 0.016 inch results. For the 0.020 inch facing group, there is no statistical debit in peel resistance for the laser-stripped group relative to the baked group, but a notable decrease for the sanded group relative to the baked results. No attempt is made in this evaluation to ascertain why the marginal but statistical increase in peel strength occurred following laser depaint for thinner facing panels (0.010 and 0.016 inch). However, it is important to note is that there is no debit in peel resistance for any of the honeycomb panels following four laser depaint operations, and in fact is superior to the hand-sanded sample group for all facing thicknesses.

Table 6. Average Peel Torque Results for Aluminum Honeycomb Panels Following Various Depaint Operations

	facing thickness (in)	core size (in)	baseline (in-lbf/in)	baked (in-lbf/in)	laser (in-lbf-in)	sanded (in-lbf/in)
Avg. Peel Torque	0.010	3/16	30.1	29.4	30.2	28.4
std dev			0.9	0.8	1.0	1.7
Avg. Peel Torque	0.016	3/16	29.2	29.1	31.3	26.4
std dev			1.2	1.0	1.3	0.9
Avg. Peel Torque	0.020	1/4	27.3	27.2	27.3	25.4
std dev			1.2	0.8	1.7	0.9

3.2.2 Flatwise Tension

The average flatwise tension strength results are shown in Table 7. Individual flatwise tension results are available in Ref 4. Average strength results show that for each facing thickness, the highest average results are for the baked condition, with the baseline and laser stripped results similar to each other and slightly lower than the baked group. Again, as with the peel results just described, the lowest flatwise strengths for each de-paint condition were achieved on the 0.020 facing panels and again are believed attributed to the slightly larger core size.

For the two thin facings, both with the 3/16 inch core, nearly all samples failed through the middle of the aluminum core and not in the adhesive bond. A photo illustrating this failure mode is furnished in Figure 14. Results for the laser-stripped group were similar to or greater than both the baseline and baked results, with average core strength lowest for the hand sanded group. Since all of the two thinner facing panels failed through the aluminum honeycomb core, the influence of the depaint operation on the bondline strength is inconclusive; however the bondline strength in all cases is greater than the aluminum core strength properties.

The results for the thickest facing material (0.020 inch) show a similar trend of highest average strength for the baked sample group, with the baseline (no bake) group being the lowest average. Failure mode for nearly all of the 0.020 inch samples was a cohesive failure in the bond region between the core and facings. Worth noting is the failure location (i.e., failure side: stripped or non-stripped skin) which is reported on in Ref. 4. For laser and hand stripped samples that failed via cohesive failures, approximately half of them failed on the stripped panel side; the other half failed on the opposite face (non-stripped panel surface). Statistical comparisons (90% CI) between the baked and laser groups indicate the mean strength values between these two sample groups are not equal, thus a statistical difference is noted. However the difference is very small and coupled with the aforementioned fact that failures occurred evenly on the stripped and non-stripped panel surfaces, such differences, while statistically real, are considered by the authors to be inconsequential. The laser group results are statistically greater than the baseline (non-baked) group, while a statistical difference is noted between baseline and baked groups, with baked being the highest. Finally, the hand sanded group results are statistically the same as both the baked and laser groups.

Table 7. Average Flatwise Tension Results for Aluminum Honeycomb Panels Following Various Depaint Operations

	face thickness (in)	core size (in)	baseline (psi)	baked (psi)	laser (psi)	sanded (psi)
Avg. Strength	0.010	3/16	1340	1387	1324	1379
std dev			36.4	25.6	39.8	36.4
Avg. Strength	0.016	3/16	1346	1377	1352	1337
std dev			27.1	54.6	40.9	28.4
Avg. Strength	0.020	1/4	1204	1288	1244	1284
std dev			42.4	38.3	50.1	72.7
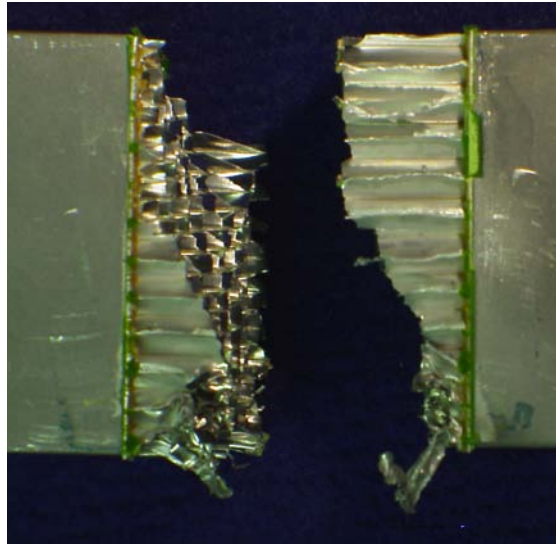
Figure 14. Illustration of a Core Failure Mode (# CO2MHBLASER04-FT2)

3.3 POLYMERIC COMPOSITES

3.3.1 In-Plane Shear

The individual results of in-plane shear tests are presented in Table 8 for non-stripped baseline (Ref.5) and hand sanded panels of 4-ply Gr-Ep panels. Comparison of the mean values at a 90% confidence level indicate a statistically significant decrease in the maximum shear stress and shear modus following the 4 hand sand operations.   Also shown in Table 8 are the 0.2% offset shear strength values which also represent a statistically significant decrease relative to the baseline non-stripped panels.

Comparison with Ref. 5 data for laser stripped samples also showed that the laser stripping processed resulted in a significant decrease in in-plane shear strength and modulus relative to the hand sanding depaint operation, though no significant difference was noted for the 0.2% offset strength.

Table 8. Individual In-Plane Shear Results for Hand-Sanded 4 ply Gr-Ep Panels

Panel #	Sample ID	Condition	Max Shear Stress (psi)	Shear Modulus (msi)	0.2% Offset Shear Stress (psi)
#C-4-1 (Ref. 5)	C-4-1	Baseline	13,520	0.769	6,596
	C-4-2	Baseline	13,786	0.795	6,770
	C-4-3	Baseline	13,536	0.794	6,872
	C-4-4	Baseline	13,491	0.802	7,333
	C-4-5	Baseline	13,556	0.816	7,069
		avg	*13,578*	*0.795*	*7,091*
		st dev	*119*	*0.017*	*231*
ARLCRS-GE-b-SAND-4	S4-1	hand sand	11,314	0.726	5,361
	S4-2	hand sand	11,190	0.696	5,692
	S4-3	hand sand	11,652	0.718	a
ARLCRS-GE-b-SAND-5	S5-1	hand sand	11,264	0.780	5,086
	S5-2	hand sand	11,410	0.675	5,885
		avg	*11,366* [b]	*0.719* [b]	*5,506* [b]
		st dev	*179*	*0.039*	*354*
Laser stripped (Ref. 5)		*avg.*	*11,011*	*0.650*	*5.834*
		st dev.	*166*	*0.015*	*347*

a – loss of transverse gage output in initial portion of test; no 0.2% offset data recorded.
b – indicates statistically significant difference from baseline results (90% CL)

3.3.2 Flexure

The results of limited flexure testing on 16-ply, Gr-Ep panels are shown in Table 9. These data are for a single baseline (Ref. 5) and two hand-sanded panels only. For the stripped group of samples (except where noted) the stripped side was loaded in compression. While results show a slight reduction in mean flex properties (strength, modulus, strain at failure), statistical comparisons at a 90% confidence level indicate no difference in flexural properties for panels that were hand-stripped. This is in contrast to the Reference 5 study, where similar Gr-Ep panels were laser depainted (4 times) to remove a similar low-observable aerospace coating. In that study, a significant decrease in flexure properties (strength and modulus) resulted from the four laser depaint operations.

Table 9. Individual Flexure Test Results for Gr-Ep [(0/0/45/-45/0/45/-45/0)s] Following Hand Sanding

Material	Sample ID	Condition	Max. Flexural Stress (psi) [a]	Flexural Modulus (msi)	Flexural Strain (%) [a]
Gr-Ep (Panel #3)	C3-1	baseline	389,188	17.24	1.51
	C3-6	baseline	382,447	17.93	1.50
	C3-3	baseline	299,016	16.55	1.31
	C3-4	baseline	318,981	16.53	1.32
	C3-5	baseline	319,215	16.57	1.35
		avg	*341,769*	*16.96*	*1.40*
		st dev	*41,107*	*0.62*	*0.10*
Gr-Ep (Panel #4)	F4-1	sanded	278,700[b]	16.98[b]	1.18[b]
	F4-2	sanded	369,479	17.41	1.48
	F4-3	sanded	362,104	17.66	1.42
Gr-Ep (Panel #5)	F5-1	sanded	250,424	16.09	1.29
	F5-2	sanded	282,811	15.75	1.32
	F5-3	sanded	275,000	16.73	1.30
		avg	*307,964*	*16.73*	*1.36*
		st dev	*54,188*	*0.82*	*0.08*
Gr-Ep (Ref. 5)	S-5-13	*laser, avg*	*221,190*	*13.51*	*1.24*
		st dev	*8,331*	*0.37*	*0.08*

a- max flex strength and stain determined at first measureable load drop
b- stripped side in tension; excluded from averages.

4. CONCLUSIONS

An evaluation program was conducted to develop and compare certain mechanical properties of a variety of thin skin aluminum and composite structural materials following a variety of standard and not-so standard paint removal operations. Results of tests performed on thin aluminum sheet, aluminum honeycomb, and limited Gr-Ep panels are outlined in the following.

- For 2024-T3 and 7075-T6 aluminum sheet, nominal 0.025" thick, tensile (UTS) and yield strength (YS) are generally unaffected by any of the depaint operations examined. A slight decrease in both YS and UTS were observed for the 2024 samples following 1 chemical strip cycle, relative to the unstripped baked group, though no decrease was noted for the 4 chemical strip samples. Also, a slight decrease in YS and UTS was seen following panels that underwent 4 hand sanding operations.

- Results of smooth and notched fatigue testing on the 2024 sheet samples showed consistent decrease in fatigue life for the majority of depaint technologies examined. In three of the four cases (smooth and notched; two stress levels) fatigue lives were decreased slightly following the chemical stripping. For the 7075 sheet materials, results were similar. Again in three of four test cases, fatigue life was reduced following chemical stripping. For the other methods, no consistent decrease in life relative to the basked baseline group was noted.

- Average peel resistance or peel torque was consistent for the majority of depaint operations examined with the sole exception of the hand sanded group, where a statistical debit was seen for two of the three facing thicknesses examined. Average peel torque for laser stripped honeycomb panels were equal to or slightly higher than the baked or baseline groups for all facing thicknesses.

- Flatwise tension testing on honeycomb panels with 0.010 and 0.016 inch thick face sheets resulted in failures through the aluminum honeycomb core material; hence the influence of depaint process on the adhesive bond is inconclusive. For the thicker 0.020 inch face sheet panels, laser stripped panel results were similar to baseline panels, but marginally lower than the baked only panels which saw a slight increase in strength following the four baked cycles. The hand-sanded panel group was similar to both the baked and laser stripped samples with respect to flatwise tension properties.

- The results of limited in-plane-shear testing on 4-ply Gr-Ep baseline (non-stripped) and hand-sanded samples showed a statistical decrease in shear strength and shear modulus following four sanding operations. Reference data on similar Gr-Ep materials that were laser stripped reported a similar decrease in shear properties following four laser depaint operations.

- Limited flexure testing on 16-ply Gr-Ep materials that were hand-sanded saw no statistical debit in flexure properties (strength or modulus) after four depaint operations. This is in contrast to previous work for similar laser stripped Gr-Ep materials, where a debit was realized following four laser depaint operations.

5. REFERENCES

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6. Standard Test Methods for Tension Testing of Metallic Materials, ASTM E 8-00, *Annual Book of ASTM Standards*.

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8. Standard Test Method for Climbing Drum Peel for Adhesives, ASTM 1781-98 (Reapproved 2004), *Annual ASTM Book of Standards.*

9. Standard Test Method for Flatwise Tensile Strength of Sandwich Constructions, ASTM C297-94 (Reapproved 1999), *Annual ASTM Book of Standards.*

10. Standard Test Method for In-Plane Shear Response of Polymer Matrix Composite Materials by Tensile Test of a ±45° Laminate, ASTM D3518D 3518M-94 (Reapproved 2007), *Annual ASTM Book of Standards.*

11. Standard Test Method for Flexural Properties of Unreinforced and Reinforced Plastics and Electrical Insulating Materials by Four-Point Bending, ASTM D6272-02, *Annual ASTM Book of Standards.*

12. *Metallic Materials Properties Development and Standardization (MMPDS)* Handbook, MMPDS-03, October 2006.

APPENDIX
Individual Tensile Test Data

Specimen ID	Panel ID	Sheet Alloy	Stripper Type	Number of Strip Cycles	YS (ksi)	UTS (ksi)	Elongation (%)
2bB1-N0-T1	Al-2b-BASELINE-1	2024-T3	none	0	52.4	70.6	18%
2bB1-N0-T2	Al-2b-BASELINE-1	2024-T3	none	0	52.5	70.7	17%
2bB1-N0-T3	Al-2b-BASELINE-1	2024-T3	none	0	53.1	70.9	17%
2bB1-N0-T4	Al-2b-BASELINE-1	2024-T3	none	0	52.8	71.2	18%
2bB1-N0-T5	Al-2b-BASELINE-1	2024-T3	none	0	53.1	71.2	17%
2bB1-N0-T6	Al-2b-BASELINE-1	2024-T3	none	0	53.1	71.1	9%
2bB1-N0-T7	Al-2b-BASELINE-1	2024-T3	none	0	53.2	71.8	17%
2bB2-N0-T1	Al-2b-BASELINE-2	2024-T3	none	0	53.0	71.6	17%
2bB2-N0-T2	Al-2b-BASELINE-2	2024-T3	none	0	53.7	72.6	16%
2bB2-N0-T3	Al-2b-BASELINE-2	2024-T3	none	0	53.2	70.5	18%
2bB2-N0-T4	Al-2b-BASELINE-2	2024-T3	none	0	53.5	72.7	16%
2bB2-N0-T5	Al-2b-BASELINE-2	2024-T3	none	0	52.9	71.2	17%
2bB2-N0-T6	Al-2b-BASELINE-2	2024-T3	none	0	53.4	71.8	17%
2bB2-N0-T7	Al-2b-BASELINE-2	2024-T3	none	0	53.4	72.0	17%
		2024-T3	**none**	**avg:**	**53.1**	**71.4**	**16.4%**
				st dev:	**0.37**	**0.71**	**2.3%**
2bBK4-B4-T1	Al-2b-BAKE-4	2024-T3	baked	4	52.4	71.6	18%
2bBK4-B4-T2	Al-2b-BAKE-4	2024-T3	baked	4	52.5	71.3	17%
2bBK4-B4-T3	Al-2b-BAKE-4	2024-T3	baked	4	53.0	71.4	16%
2bBK4-B4-T4	Al-2b-BAKE-4	2024-T3	baked	4	53.0	71.2	16%
2bBK4-B4-T5	Al-2b-BAKE-4	2024-T3	baked	4	53.0	71.7	16%
2bBK4-B4-T6	Al-2b-BAKE-4	2024-T3	baked	4	52.9	71.5	17%
2bBK4-B4-T7	Al-2b-BAKE-4	2024-T3	baked	4	52.4	71.9	17%
2bBK5-B4-T1	Al-2b-BAKE-5	2024-T3	baked	4	52.9	71.5	17%
2bBK5-B4-T2	Al-2b-BAKE-5	2024-T3	baked	4	52.7	71.4	17%
2bBK5-B4-T3	Al-2b-BAKE-5	2024-T3	baked	4	52.6	71.4	17%
2bBK5-B4-T4	Al-2b-BAKE-5	2024-T3	baked	4	52.8	71.3	18%
2bBK5-B4-T5	Al-2b-BAKE-5	2024-T3	baked	4	52.8	71.4	17%
2bBK5-B4-T6	Al-2b-BAKE-5	2024-T3	baked	4	52.8	71.6	18%
2bBK5-B4-T7	Al-2b-BAKE-5	2024-T3	baked	4	52.5	71.3	16%
		2024-T3	**4 bake cycles**	**avg:**	**52.7**	**71.5**	**17.0%**
				st dev:	**0.21**	**0.19**	**0.6%**
2bS5-L4-T1	Al-2b-STD-5	2024-T3	laser	4	52.3	70.9	16%
2bS5-L4-T2	Al-2b-STD-5	2024-T3	laser	4	52.2	71.2	17%
2bS5-L4-T3	Al-2b-STD-5	2024-T3	laser	4	53.2	72.2	17%
2bS5-L4-T4	Al-2b-STD-5	2024-T3	laser	4	52.9	71.7	16%
2bS5-L4-T5	Al-2b-STD-5	2024-T3	laser	4	53.2	72.7	18%
2bS5-L4-T6	Al-2b-STD-5	2024-T3	laser	4	53.0	72.8	16%
2bS6-L4-T1	Al-2b-STD-6	2024-T3	laser	4	52.6	71.1	17%
2bS6-L4-T2	Al-2b-STD-6	2024-T3	laser	4	52.6	71.2	17%

2bS6-L4-T3	Al-2b-STD-6	2024-T3	laser	4	52.7	71.7	18%
2bS6-L4-T4	Al-2b-STD-6	2024-T3	laser	4	52.6	71.1	16%
2bS6-L4-T5	Al-2b-STD-6	2024-T3	laser	4	52.8	71.0	17%
2bS6-L4-T6	Al-2b-STD-6	2024-T3	laser	4	52.6	71.0	17%
		2024-T3	**4 laser strips**	**avg:**	**52.7**	**71.5**	**16.9%**
				st dev:	**0.30**	**0.67**	**0.6%**
2cS5-L4-T1	Al-2c-STD-5	2024 clad	laser	4	49.2	65.9	15%
2cS5-L4-T2	Al-2c-STD-5	2024 clad	laser	4	49.0	65.7	16%
2cS5-L4-T3	Al-2c-STD-5	2024 clad	laser	4	49.2	65.9	17%
2cS5-L4-T4	Al-2c-STD-5	2024 clad	laser	4	48.8	65.6	17%
2cS5-L4-T5	Al-2c-STD-5	2024 clad	laser	4	49.1	65.8	17%
2cS5-L4-T6	Al-2c-STD-5	2024 clad	laser	4	48.7	65.3	16%
		2024 clad	**4 laser strips**	**avg:**	**49.0**	**65.7**	**16.3%**
				st dev:	**0.19**	**0.23**	**0.6%**
2bC2-C1-T1	Al-2b-CHEM-2	2024-T3	chem	1	52.8	71.4	17%
2bC2-C1-T2	Al-2b-CHEM-2	2024-T3	chem	1	51.9	70.7	17%
2bC2-C1-T3	Al-2b-CHEM-2	2024-T3	chem	1	52.5	71.1	17%
2bC2-C1-T4	Al-2b-CHEM-2	2024-T3	chem	1	52.4	71.4	17%
2bC2-C1-T5	Al-2b-CHEM-2	2024-T3	chem	1	52.7	71.6	17%
2bC2-C1-T6	Al-2b-CHEM-2	2024-T3	chem	1	52.6	71.5	17%
		2024-T3	**1 chem strip**	**avg:**	**52.5**	**71.3**	**17.1%**
				st dev:	**0.30**	**0.33**	**0.3%**
2bCH5-C4-T1	Al-2b-CHEM-5	2024-T3	chem	4	53.87	72.64	16.8%
2bCH5-C4-T2	Al-2b-CHEM-5	2024-T3	chem	4	53.98	72.76	17.1%
2bCH5-C4-T3	Al-2b-CHEM-5	2024-T3	chem	4	53.89	72.83	16.9%
2bCH5-C4-T4	Al-2b-CHEM-5	2024-T3	chem	4	53.90	72.85	16.3%
2bCH5-C4-T5	Al-2b-CHEM-5	2024-T3	chem	4	53.98	72.85	17.2%
2bCH5-C4-T6	Al-2b-CHEM-5	2024-T3	chem	4	53.97	73.16	16.6%
		2024-T3	**4 chem strips**	**avg:**	**53.9**	**72.8**	**16.8%**
				st dev:	**0.05**	**0.17**	**0.3%**
72b-PMB4-T1	072b-PMB4	2024-T3	PMB	4	53.3	72.5	18.1%
72b-PMB4-T2	072b-PMB4	2024-T3	PMB	4	53.4	72.4	15.9%
72b-PMB4-T3	072b-PMB4	2024-T3	PMB	4	53.4	72.6	18.6%
72b-PMB4-T4	072b-PMB4	2024-T3	PMB	4	53.0	72.1	16.3%
072bPMB5-T1	072b-PMB5	2024-T3	PMB	4	53.5	72.4	17.8%
072bPMB5-T2	072b-PMB5	2024-T3	PMB	4	53.6	72.6	17.6%
072bPMB5-T3	072b-PMB5	2024-T3	PMB	4	53.5	71.9	17.3%
072bPMB5-T4	072b-PMB5	2024-T3	PMB	4	53.7	72.3	16.2%
		2024-T3	**4 PMB strips**	**avg:**	**53.4**	**72.4**	**17.2%**
				st dev:	**0.21**	**0.26**	**1.0%**

2bSAND4-T1	072bSAND4	2024-T3	hand sand	4	52.1	70.3	16%
2bSAND4-T2	072bSAND4	2024-T3	hand sand	4	52.4	71.3	17%
2bSAND4-T3	072bSAND4	2024-T3	hand sand	4	52.3	71.3	18%
2bSAND4-T4	072bSAND4	2024-T3	hand sand	4	52.3	71.1	16%
2bSAND5-T1	072bSAND5	2024-T3	hand sand	4	52.1	70.3	17%
2bSAND5-T2	072bSAND5	2024-T3	hand sand	4	52.3	70.8	18%
2bSAND5-T3	072bSAND5	2024-T3	hand sand	4	52.2	70.9	16%
2bSAND5-T4	072bSAND5	2024-T3	hand sand	4	52.4	71.2	17%
		2024-T3	**4 hand sand**	**avg:**	**52.3**	**70.9**	**16.9%**
				st dev:	**0.13**	**0.41**	**0.6%**
7bB1-N0-T1	Al-7b-BASELINE-1	7075-T6	none	0	74.3	84.2	14%
7bB1-N0-T2	Al-7b-BASELINE-1	7075-T6	none	0	74.4	85.3	14%
7bB1-N0-T3	Al-7b-BASELINE-1	7075-T6	none	0	74.6	85.4	14%
7bB1-N0-T4	Al-7b-BASELINE-1	7075-T6	none	0	74.7	84.5	13%
7bB1-N0-T5	Al-7b-BASELINE-1	7075-T6	none	0	75.7	85.0	14%
7bB1-N0-T6	Al-7b-BASELINE-1	7075-T6	none	0	75.6	84.9	14%
7bB1-N0-T7	Al-7b-BASELINE-1	7075-T6	none	0	75.1	84.8	16%
7bB2-N0-T1	Al-7b-BASELINE-2	7075-T6	none	0	74.8	83.9	14%
7bB2-N0-T2	Al-7b-BASELINE-2	7075-T6	none	0	76.2	85.6	13%
7bB2-N0-T3	Al-7b-BASELINE-2	7075-T6	none	0	75.3	84.5	13%
7bB2-N0-T4	Al-7b-BASELINE-2	7075-T6	none	0	75.1	84.8	14%
7bB2-N0-T5	Al-7b-BASELINE-2	7075-T6	none	0	74.3	83.6	13%
7bB2-N0-T6	Al-7b-BASELINE-2	7075-T6	none	0	74.0	83.9	13%
7bB2-N0-T7	Al-7b-BASELINE-2	7075-T6	none	0	75.5	84.8	13%
		7075-T6	**none**	**avg:**	**75.0**	**84.7**	**13.7%**
				st dev:	**0.64**	**0.59**	**0.7%**
7bBK4-B4-T1	Al-7b-BAKE-4	7075-T6	baked	4	76.3	85.9	13%
7bBK4-B4-T2	Al-7b-BAKE-4	7075-T6	baked	4	76.3	85.4	12%
7bBK4-B4-T3	Al-7b-BAKE-4	7075-T6	baked	4	75.3	84.8	13%
7bBK4-B4-T4	Al-7b-BAKE-4	7075-T6	baked	4	75.5	85.1	12%
7bBK4-B4-T5	Al-7b-BAKE-4	7075-T6	baked	4	75.8	85.2	13%
7bBK4-B4-T6	Al-7b-BAKE-4	7075-T6	baked	4	75.9	85.0	13%
7bBK5-B4-T1	Al-7b-BAKE-5	7075-T6	baked	4	75.6	84.5	13%
7bBK5-B4-T2	Al-7b-BAKE-5	7075-T6	baked	4	75.7	84.8	14%
7bBK5-B4-T3	Al-7b-BAKE-5	7075-T6	baked	4	74.3	84.8	13%
7bBK5-B4-T4	Al-7b-BAKE-5	7075-T6	baked	4	75.7	84.9	12%
7bBK5-B4-T5	Al-7b-BAKE-5	7075-T6	baked	4	76.2	85.1	12%
7bBK5-B4-T6	Al-7b-BAKE-5	7075-T6	baked	4	76.1	85.2	12%
7bBK5-B4-T7	Al-7b-BAKE-5	7075-T6	baked	4	75.5	84.7	13%
		7075-T6	**4 bake cycles**	**avg:**	**75.7**	**85.0**	**12.7%**
				st dev:	**0.5**	**0.3**	**0.4%**

7bS5-L4-T1	Al-7b-STD-5	7075-T6	laser	4	75.0	83.5	12%
7bS5-L4-T2	Al-7b-STD-5	7075-T6	laser	4	75.3	83.8	13%
7bS5-L4-T3	Al-7b-STD-5	7075-T6	laser	4	75.1	84.6	13%
7bS5-L4-T4	Al-7b-STD-5	7075-T6	laser	4	75.7	84.2	13%
7bS5-L4-T5	Al-7b-STD-5	7075-T6	laser	4	75.1	85.0	12%
7bS5-L4-T6	Al-7b-STD-5	7075-T6	laser	4	76.0	85.1	12%
7bS6-L4-T1	Al-7b-STD-6	7075-T6	laser	4	76.2	84.8	13%
7bS6-L4-T2	Al-7b-STD-6	7075-T6	laser	4	76.4	85.0	13%
7bS6-L4-T3	Al-7b-STD-6	7075-T6	laser	4	77.2	85.8	13%
7bS6-L4-T4	Al-7b-STD-6	7075-T6	laser	4	76.1	85.1	13%
7bS6-L4-T5	Al-7b-STD-6	7075-T6	laser	4	77.1	86.0	13%
7bS6-L4-T6	Al-7b-STD-6	7075-T6	laser	4	76.9	85.9	13%
		7075-T6	**4 laser strips**	**avg:**	**76.0**	**84.9**	**12.9%**
				st dev:	**0.8**	**0.8**	**0.4%**
7bC2-C1-T1	Al-7b-CHEM-2	7075-T6	chem	1	75.2	85.1	13%
7bC2-C1-T2	Al-7b-CHEM-2	7075-T6	chem	1	75.4	85.1	13%
7bC2-C1-T3	Al-7b-CHEM-2	7075-T6	chem	1	76.0	85.1	13%
7bC2-C1-T4	Al-7b-CHEM-2	7075-T6	chem	1	75.7	84.9	14%
7bC2-C1-T5	Al-7b-CHEM-2	7075-T6	chem	1	76.0	85.3	13%
7bC2-C1-T6	Al-7b-CHEM-2	7075-T6	chem	1	75.2	84.7	14%
		7075-T6	**1 chem strip**	**avg:**	**75.6**	**85.0**	**13.2%**
				st dev:	**0.4**	**0.2**	**0.3%**
7bCH5C4-T1	Al-7b-CHEM-5	7075-T6	chem	4	77.75	86.15	13%
7bCH5C4-T2	Al-7b-CHEM-5	7075-T6	chem	4	76.85	83.62	9%
7bCH5C4-T3	Al-7b-CHEM-5	7075-T6	chem	4	77.14	85.85	13%
7bCH5C4-T4	Al-7b-CHEM-5	7075-T6	chem	4	77.38	85.69	13%
7bCH5C4-T5	Al-7b-CHEM-5	7075-T6	chem	4	77.22	85.69	13%
7bCH5C4-T6	Al-7b-CHEM-5	7075-T6	chem	4	77.14	85.22	9%
		7075-T6	**4 chem strips**	**avg:**	**77.2**	**85.4**	**11.7%**
				st dev:	**0.3**	**0.9**	**2.0%**
077bPMB4-T1	Al-7b-PMB-4	7075-T6	PMB	4	76.22	85.51	14%
077bPMB4-T2	Al-7b-PMB-4	7075-T6	PMB	4	76.67	85.56	14%
077bPMB4-T3	Al-7b-PMB-4	7075-T6	PMB	4	76.37	85.41	15%
077bPMB4-T4	Al-7b-PMB-4	7075-T6	PMB	4	76.45	85.33	13%
077bPMB5-T1	Al-7b-PMB-5	7075-T6	PMB	4	77.41	85.92	13%
077bPMB5-T2	Al-7b-PMB-5	7075-T6	PMB	4	76.83	85.76	13%
077bPMB5-T3	Al-7b-PMB-5	7075-T6	PMB	4	77.00	85.58	14%
077bPMB5-T4	Al-7b-PMB-5	7075-T6	PMB	4	76.64	85.28	13%
		7075-T6	**4 PMB strips**	**avg:**	**76.7**	**85.5**	**13.7%**
				st dev:	**0.4**	**0.2**	**0.7%**

7bSAND4-T1	Al-7b-SAND-4	7075-T6	hand sand	4	76.58	85.00	12.1%
7bSAND4-T2	Al-7b-SAND-4	7075-T6	hand sand	4	76.14	85.38	11.7%
7bSAND4-T3	Al-7b-SAND-4	7075-T6	hand sand	4	76.79	85.13	12.9%
7bSAND4-T4	Al-7b-SAND-4	7075-T6	hand sand	4	76.14	84.72	11.5%
7bSAND5-T1	Al-7b-SAND-5	7075-T6	hand sand	4	76.42	85.27	12.6%
7bSAND5-T2	Al-7b-SAND-5	7075-T6	hand sand	4	76.84	85.69	12.3%
7bSAND5-T3	Al-7b-SAND-5	7075-T6	hand sand	4	76.34	85.36	13.7%
7bSAND5-T4	Al-7b-SAND-5	7075-T6	hand sand	4	76.69	85.44	12.5%
		7075-T6	**4 hand sand**	**avg:**	**76.5**	**85.2**	**12.4%**
				st dev:	**0.3**	**0.3**	**0.7%**

Individual Fatigue Test Results
2024 Smooth Fatigue Data

Specimen ID	Panel ID	Sheet Alloy	Stripping Type	Number of Strip Events	Max Stress (ksi)	Str Ratio (R)	Cycles to Failure
2bB1-N0-F1	Al-2b-BASELINE-1	2024-T3	NONE	0	45.0	0.1	298154
2bB1-N0-F4	Al-2b-BASELINE-1	2024-T3	NONE	0	55.0	0.1	39314
2bB1-N0-F9	Al-2b-BASELINE-1	2024-T3	NONE	0	52.0	0.1	80734
2bB1-N0-F12	Al-2b-BASELINE-1	2024-T3	NONE	0	48.0	0.1	186052
2bB1-N0-F2	Al-2b-BASELINE-1	2024-T3	NONE	0	45.0	0.1	419002
2bB1-N0-F7	Al-2b-BASELINE-1	2024-T3	NONE	0	55.0	0.1	41124
2bB1-N0-F5	Al-2b-BASELINE-1	2024-T3	NONE	0	45.0	0.1	334738
2bB1-N0-F11	Al-2b-BASELINE-1	2024-T3	NONE	0	55.0	0.1	45766
2bB2-N0-F9	Al-2b-BASELINE-2	2024-T3	NONE	0	45.0	0.1	378969
2bB2-N0-F7	Al-2b-BASELINE-2	2024-T3	NONE	0	45.0	0.1	211754
2bB2-N0-F8	Al-2b-BASELINE-2	2024-T3	NONE	0	55.0	0.1	35092
2bB2-N0-F11	Al-2b-BASELINE-2	2024-T3	NONE	0	55.0	0.1	41514
2bB2-N0-F10	Al-2b-BASELINE-2	2024-T3	NONE	0	42.0	0.1	3098368
2bB2-N0-F1	Al-2b-BASELINE-2	2024-T3	NONE	0	45.0	0.1	233841
2bB2-N0-F2	Al-2b-BASELINE-2	2024-T3	NONE	0	40.0	0.1	10000000
2bB2-N0-F4	Al-2b-BASELINE-2	2024-T3	NONE	0	48.0	0.1	129703
2bB2-N0-F5	Al-2b-BASELINE-2	2024-T3	NONE	0	60.0	0.1	33471
2bBK4-B4-F1	Al-2b-BAKE-4	2024-T3	NONE	4 baked	55.0	0.1	57761
2bBK4-B4-F2	Al-2b-BAKE-4	2024-T3	NONE	4 baked	45.0	0.1	184449
2bBK4-B4-F5	Al-2b-BAKE-4	2024-T3	NONE	4 baked	55.0	0.1	42575
2bBK4-B4-F8	Al-2b-BAKE-4	2024-T3	NONE	4 baked	45.0	0.1	209530
2bBK4-B4-F11	Al-2b-BAKE-4	2024-T3	NONE	4 baked	45.0	0.1	213022
2bBK4-B4-F14	Al-2b-BAKE-4	2024-T3	NONE	4 baked	55.0	0.1	49501
2bBK5-B4-F1	Al-2b-BAKE-5	2024-T3	NONE	5 baked	55.0	0.1	57620
2bBK5-B4-F2	Al-2b-BAKE-5	2024-T3	NONE	5 baked	45.0	0.1	149018
2bBK5-B4-F3	Al-2b-BAKE-5	2024-T3	NONE	5 baked	55.0	0.1	46929

Specimen ID	Panel ID	Sheet Alloy	Stripping Type	Number of Strip Events	Max Stress (ksi)	Str Ratio (R)	Cycles to Failure
2bS5-L4-F10	A-2b-STD-5	2024-T3	Laser	4	45.0	0.1	155826
2bS5-L4-F12	A-2b-STD-5	2024-T3	Laser	4	55.0	0.1	38022
2bS6-L4-F1	Al-2b-STD-6	2024-T3	Laser	4	45.0	0.1	141937
2bS6-L4-F2	Al-2b-STD-6	2024-T3	Laser	4	45.0	0.1	167383
2bS6-L4-F3	Al-2b-STD-6	2024-T3	Laser	4	55.0	0.1	37570
2bS6-L4-F5	Al-2b-STD-6	2024-T3	Laser	4	55.0	0.1	33930
2bS6-L4-F6	Al-2b-STD-6	2024-T3	Laser	4	45.0	0.1	154986
2bS6-L4-F9	Al-2b-STD-6	2024-T3	Laser	4	45.0	0.1	312033
2bS6-L4-F10	Al-2b-STD-6	2024-T3	Laser	4	55.0	0.1	37519
2bS6-L4-F11	Al-2b-STD-6	2024-T3	Laser	4	55.0	0.1	50110
2cS5-L4-F1	A-2c-STD-5	2024-T3	Laser (clad)	4	45.0	0.1	98212
2cS5-L4-F2	A-2c-STD-5	2024-T3	Laser (clad)	4	55.0	0.1	28486
2cS5-L4-F3	A-2c-STD-5	2024-T3	Laser (clad)	4	55.0	0.1	37266
2cS5-L4-F4	A-2c-STD-5	2024-T3	Laser (clad)	4	45.0	0.1	90179
2cS5-L4-F5	A-2c-STD-5	2024-T3	Laser (clad)	4	45.0	0.1	109497
2cS5-L4-F6	A-2c-STD-5	2024-T3	Laser (clad)	4	55.0	0.1	28612
2cS5-L4-F8	A-2c-STD-5	2024-T3	Laser (clad)	4	45.0	0.1	105998
2cS5-L4-F9	A-2c-STD-5	2024-T3	Laser (clad)	4	55.0	0.1	31016
2cS5-L4-F11	A-2c-STD-5	2024-T3	Laser (clad)	4	45.0	0.1	68299
2cS5-L4-F12	A-2c-STD-5	2024-T3	Laser (clad)	4	55.0	0.1	18569

Specimen ID	Panel ID	Sheet Alloy	Stripping Type	Number of Strip Events	Max Stress (ksi)	Str Ratio (R)	Cycles to Failure
2bC2-C1-F1	Al-2b-CHEM-2	2024-T3	CHEM	1	45.0	0.1	145239
2bC2-C1-F2	Al-2b-CHEM-2	2024-T3	CHEM	1	55.0	0.1	48802
2bC2-C1-F3	Al-2b-CHEM-2	2024-T3	CHEM	1	45.0	0.1	255773
2bC2-C1-F4	Al-2b-CHEM-2	2024-T3	CHEM	1	45.0	0.1	134742
2bC2-C1-F5	Al-2b-CHEM-2	2024-T3	CHEM	1	55.0	0.1	63121
2bC2-C1-F7	Al-2b-CHEM-2	2024-T3	CHEM	1	45.0	0.1	207192
2bC2-C1-F9	Al-2b-CHEM-2	2024-T3	CHEM	1	55.0	0.1	37404
2bC2-C1-F11	Al-2b-CHEM-2	2024-T3	CHEM	1	55.0	0.1	72978
2bC2-C1-F12	Al-2b-CHEM-2	2024-T3	CHEM	1	45.0	0.1	258484
2bC2-C1-F13	Al-2b-CHEM-2	2024-T3	CHEM	1	55.0	0.1	67402
2bC2-C1-F14	Al-2b-CHEM-2	2024-T3	CHEM	1	45.0	0.1	106035
2bCH5-C4-F1	Al-2b-CHEM-4	2024-T3	CHEM	4	45.0	0.1	137805
2bCH5-C4-F2	Al-2b-CHEM-4	2024-T3	CHEM	4	55.0	0.1	46900
2bCH5-C4-F4	Al-2b-CHEM-4	2024-T3	CHEM	4	45.0	0.1	201373
2bCH5-C4-F5	Al-2b-CHEM-4	2024-T3	CHEM	4	55.0	0.1	16162
2bCH5-C4-F6	Al-2b-CHEM-4	2024-T3	CHEM	4	45.0	0.1	76063
2bCH5-C4-F7	Al-2b-CHEM-4	2024-T3	CHEM	4	45.0	0.1	142268
2bCH5-C4-F8	Al-2b-CHEM-4	2024-T3	CHEM	4	55.0	0.1	46332
2bCH5-C4-F9	Al-2b-CHEM-4	2024-T3	CHEM	4	45.0	0.1	168232
2bCH5-C4-F10	Al-2b-CHEM-4	2024-T3	CHEM	4	55.0	0.1	47646
2bCH5-C4-F11	Al-2b-CHEM-4	2024-T3	CHEM	4	45.0	0.1	29508

Specimen ID	Panel ID	Sheet Alloy	Stripping Type	Number of Strip Events	Max Stress (ksi)	Str Ratio (R)	Cycles to Failure
2bCH5-C4-F12	Al-2b-CHEM-4	2024-T3	CHEM	4	55.0	0.1	38438
2bPMB-4-F1	Al-2b-PMB-4	2024-T3	PMB	4	55.0	0.1	48267
2bPMB-4-F2	Al-2b-PMB-4	2024-T3	PMB	4	45.0	0.1	182440
2bPMB-4-F3	Al-2b-PMB-4	2024-T3	PMB	4	55.0	0.1	36406
2bPMB-4-F4	Al-2b-PMB-4	2024-T3	PMB	4	45.0	0.1	285769
2bPMB-4-F6	Al-2b-PMB-4	2024-T3	PMB	4	55.0	0.1	52088
2bPMB-4-F7	Al-2b-PMB-4	2024-T3	PMB	4	45.0	0.1	196509
2bPMB-5-F1	Al-2b-PMB-5	2024-T3	PMB	4	55.0	0.1	49769
2bPMB-5-F2	Al-2b-PMB-5	2024-T3	PMB	4	45.0	0.1	231032
2bPMB-5-F3	Al-2b-PMB-5	2024-T3	PMB	4	45.0	0.1	159163
2bPMB-5-F4	Al-2b-PMB-5	2024-T3	PMB	4	55.0	0.1	51729
2bPMB-5-F6	Al-2b-PMB-5	2024-T3	PMB	4	45.0	0.1	178254
2bPMB-5-F7	Al-2b-PMB-5	2024-T3	PMB	4	55.0	0.1	42731
2bsand-4-F2	Al-2b-SAND-4	2024-T3	Hand Sanded	4	45.0	0.1	193877
2bsand-4-F3	Al-2b-SAND-4	2024-T3	Hand Sanded	4	55.0	0.1	32899
2bsand-4-F4	Al-2b-SAND-4	2024-T3	Hand Sanded	4	55.0	0.1	28346
2bsand-4-F5	Al-2b-SAND-4	2024-T3	Hand Sanded	4	45.0	0.1	191746
2bsand-4-F6	Al-2b-SAND-4	2024-T3	Hand Sanded	4	45.0	0.1	213971
2bsand-4-F7	Al-2b-SAND-4	2024-T3	Hand Sanded	4	55.0	0.1	45749
2bsand-5-F2	Al-2b-SAND-5	2024-T3	Hand Sanded	4	55.0	0.1	22010
2bsand-5-F3	Al-2b-SAND-5	2024-T3	Hand Sanded	4	45.0	0.1	285897
2bsand-5-F4	Al-2b-SAND-5	2024-T3	Hand Sanded	4	45.0	0.1	172384
2bsand-5-F5	Al-2b-SAND-5	2024-T3	Hand Sanded	4	55.0	0.1	73086
2bsand-5-F6	Al-2b-SAND-5	2024-T3	Hand Sanded	4	55.0	0.1	21889
2bsand-5-F7	Al-2b-SAND-5	2024-T3	Hand Sanded	4	45.0	0.1	248128

2024 Notched Fatigue Data

Specimen ID	Panel ID	Sheet Alloy	Stripping Type	Max Net Stress (ksi)	Stress Ratio, R	Cycles to Fail.
2bB1-N0-NF2	Al-2b-BASELINE-1	2024-T3	NONE	22.0	0.1	1,179,203
2bB1-N0-NF5	Al-2b-BASELINE-1	2024-T3	NONE	30.0	0.1	65,755
2bB1-N0-NF7	Al-2b-BASELINE-1	2024-T3	NONE	22.0	0.1	175,626
2bB1-N0-NF8	Al-2b-BASELINE-1	2024-T3	NONE	22.0	0.1	190,974
2bB1-N0-NF9	Al-2b-BASELINE-1	2024-T3	NONE	30.0	0.1	57,124
2bB1-N0-NF14	Al-2b-BASELINE-1	2024-T3	NONE	30.0	0.1	54,792
2bB1-N0-NF1	Al-2b-BASELINE-1	2024-T3	NONE	21.0	0.1	477,929
2bB1-N0-NF3	Al-2b-BASELINE-1	2024-T3	NONE	24.0	0.1	165,875
2bB1-N0-NF6	Al-2b-BASELINE-1	2024-T3	NONE	28.0	0.1	75,867
2bB1-N0-NF11	Al-2b-BASELINE-1	2024-T3	NONE	20.0	0.1	10,000,000
2bB2-N0-NF5	Al-2b-BASELINE-2	2024-T3	NONE	24.0	0.1	155,722
2bB2-N0-NF8	Al-2b-BASELINE-2	2024-T3	NONE	22.0	0.1	208,872
2bB2-N0-NF12	Al-2b-BASELINE-2	2024-T3	NONE	30.0	0.1	58,124
2bB2-N0-NF14	Al-2b-BASELINE-2	2024-T3	NONE	32.0	0.1	48,415
2bB2-N0-NF3	Al-2b-BASELINE-2	2024-T3	NONE	22.0	0.1	287,871
2bB2-N0-NF4	Al-2b-BASELINE-2	2024-T3	NONE	22.0	0.1	306,144
2bB2-N0-NF9	Al-2b-BASELINE-2	2024-T3	NONE	30.0	0.1	45,839
2bB2-N0-NF13	Al-2b-BASELINE-2	2024-T3	NONE	30.0	0.1	48,801
2bBK4-B4-NF2	Al-2b-BAKED-4	2024-T3	NONE	22.0	0.1	173,961
2bBK4-B4-NF5	Al-2b-BAKED-4	2024-T3	NONE	22.0	0.1	145,850
2bBK4-B4-NF6	Al-2b-BAKED-4	2024-T3	NONE	22.0	0.1	251,580
2bBK4-B4-NF7	Al-2b-BAKED-4	2024-T3	NONE	30.0	0.1	57,065
2bBK4-B4-NF13	Al-2b-BAKED-4	2024-T3	NONE	30.0	0.1	47,451
2bBK4-B4-NF14	Al-2b-BAKED-4	2024-T3	NONE	30.0	0.1	47,338
2bBK5-B4-NF1	Al-2b-BAKED-5	2024-T3	NONE	22.0	0.1	164,797
2bBK5-B4-NF3	Al-2b-BAKED-5	2024-T3	NONE	30.0	0.1	52,662

Specimen ID	Panel ID	Sheet Alloy	Stripping Type	Max Net Stress (ksi)	Stress Ratio, R	Cycles to Fail.
2bBK5-B4-NF7	Al-2b-BAKED-5	2024-T3	NONE	22.0	0.1	138,633
2bBK5-B4-NF9	Al-2b-BAKED-5	2024-T3	NONE	22.0	0.1	183,096
2bBK5-B4-NF10	Al-2b-BAKED-5	2024-T3	NONE	30.0	0.1	62,937
2bBK5-B4-NF14	Al-2b-BAKED-5	2024-T3	NONE	30.0	0.1	52,915
2bS5-L4-NF1	Al-2b-STD-5	2024-T3	Laser	30.0	0.1	47,061
2bS5-L4-NF2	Al-2b-STD-5	2024-T3	Laser	22.0	0.1	225,293
2bS5-L4-NF5	Al-2b-STD-5	2024-T3	Laser	30.0	0.1	58,108
2bS5-L4-NF6	Al-2b-STD-5	2024-T3	Laser	22.0	0.1	2,493,258
2bS5-L4-NF8	Al-2b-STD-5	2024-T3	Laser	30.0	0.1	51,500
2bS5-L4-NF9	Al-2b-STD-5	2024-T3	Laser	22.0	0.1	216,645
2bS6-L4-NF2	Al-2b-STD-6	2024-T3	Laser	30.0	0.1	54,677
2bS6-L4-NF5	Al-2b-STD-6	2024-T3	Laser	30.0	0.1	55,705
2bS6-L4-NF6	Al-2b-STD-6	2024-T3	Laser	22.0	0.1	373,259
2bS6-L4-NF9	Al-2b-STD-6	2024-T3	Laser	22.0	0.1	1,795,994
2bS6-L4-NF10	Al-2b-STD-6	2024-T3	Laser	30.0	0.1	53,708
2bS6-L4-NF12	Al-2b-STD-6	2024-T3	Laser	22.0	0.1	6,364,421
2cS5-L4-NF1	Al-2c-STD-5	2024-T3	Laser (clad)	22.0	0.1	157,110
2cS5-L4-NF2	Al-2c-STD-5	2024-T3	Laser (clad)	30.0	0.1	42,138
2cS5-L4-NF3	Al-2c-STD-5	2024-T3	Laser (clad)	22.0	0.1	152,315
2cS5-L4-NF4	Al-2c-STD-5	2024-T3	Laser (clad)	30.0	0.1	40,890
2cS5-L4-NF5	Al-2c-STD-5	2024-T3	Laser (clad)	22.0	0.1	131,966
2cS5-L4-NF6	Al-2c-STD-5	2024-T3	Laser (clad)	30.0	0.1	44,472
2cS5-L4-NF7	Al-2c-STD-5	2024-T3	Laser (clad)	22.0	0.1	156,629
2cS5-L4-NF8	Al-2c-STD-5	2024-T3	Laser (clad)	30.0	0.1	35,892
2cS5-L4-NF9	Al-2c-STD-5	2024-T3	Laser (clad)	30.0	0.1	40,192
2cS5-L4-NF10	Al-2c-STD-5	2024-T3	Laser (clad)	22.0	0.1	149,567

Specimen ID	Panel ID	Sheet Alloy	Stripping Type	Max Net Stress (ksi)	Stress Ratio, R	Cycles to Fail.
2cS5-L4-NF11	Al-2c-STD-5	2024-T3	Laser (clad)	**22.0**	0.1	140,703
2cS5-L4-NF12	Al-2c-STD-5	2024-T3	Laser (clad)	30.0	0.1	50,665
2bC2-C1-NF1	Al-2b-CHEM-2	2024-T3	CHEM	**22.0**	0.1	845,714
2bC2-C1-NF3	Al-2b-CHEM-2	2024-T3	CHEM	**22.0**	0.1	318,849
2bC2-C1-NF4	Al-2b-CHEM-2	2024-T3	CHEM	30.0	0.1	52,087
2bC2-C1-NF6	Al-2b-CHEM-2	2024-T3	CHEM	**22.0**	0.1	436,531
2bC2-C1-NF7	Al-2b-CHEM-2	2024-T3	CHEM	30.0	0.1	52,273
2bC2-C1-NF8	Al-2b-CHEM-2	2024-T3	CHEM	30.0	0.1	56,107
2bC2-C1-NF9	Al-2b-CHEM-2	2024-T3	CHEM	**22.0**	0.1	215,985
2bC2-C1-NF10	Al-2b-CHEM-2	2024-T3	CHEM	30.0	0.1	50,786
2bC2-C1-NF11	Al-2b-CHEM-2	2024-T3	CHEM	**22.0**	0.1	213,275
2bC2-C1-NF12	Al-2b-CHEM-2	2024-T3	CHEM	30.0	0.1	45,687
2bC2-C1-NF13	Al-2b-CHEM-2	2024-T3	CHEM	30.0	0.1	59,359
2bC2-C1-NF14	Al-2b-CHEM-2	2024-T3	CHEM	**22.0**	0.1	168,749
2bCH5-C4-NF1	Al-2b-CHEM-4	2024-T3	CHEM	22.0	0.1	118,829
2bCH5-C4-NF2	Al-2b-CHEM-4	2024-T3	CHEM	30.0	0.1	55,967
2bCH5-C4-NF3	Al-2b-CHEM-4	2024-T3	CHEM	22.0	0.1	331,910
2bCH5-C4-NF4	Al-2b-CHEM-4	2024-T3	CHEM	30.0	0.1	42,733
2bCH5-C4-NF5	Al-2b-CHEM-4	2024-T3	CHEM	22.0	0.1	247,519
2bCH5-C4-NF6	Al-2b-CHEM-4	2024-T3	CHEM	30.0	0.1	45,422
2bCH5-C4-NF7	Al-2b-CHEM-4	2024-T3	CHEM	22.0	0.1	439,023
2bCH5-C4-NF9	Al-2b-CHEM-4	2024-T3	CHEM	30.0	0.1	48,574
2bCH5-C4-NF10	Al-2b-CHEM-4	2024-T3	CHEM	22.0	0.1	161,644
2bCH5-C4-NF11	Al-2b-CHEM-4	2024-T3	CHEM	30.0	0.1	46,303
2bPMB-4-NF1	Al-2b-PMB-4	2024-T3	PMB	22.0	0.1	188,210
2bPMB-4-NF2	Al-2b-PMB-4	2024-T3	PMB	30.0	0.1	50,524

Specimen ID	Panel ID	Sheet Alloy	Stripping Type	Max Net Stress (ksi)	Stress Ratio, R	Cycles to Fail.
2bPMB-4-NF3	Al-2b-PMB-4	2024-T3	PMB	22.0	0.1	231,120
2bPMB-4-NF4	Al-2b-PMB-4	2024-T3	PMB	30.0	0.1	50,207
2bPMB-4-NF5	Al-2b-PMB-4	2024-T3	PMB	22.0	0.1	216,957
2bPMB-4-NF6	Al-2b-PMB-4	2024-T3	PMB	30.0	0.1	54,511
2bPMB-4-NF7	Al-2b-PMB-4	2024-T3	PMB	22.0	0.1	186,119
2bPMB-5-NF1	Al-2b-PMB-5	2024-T3	PMB	22.0	0.1	1,181,482
2bPMB-5-NF2	Al-2b-PMB-5	2024-T3	PMB	30.0	0.1	59,191
2bPMB-5-NF5	Al-2b-PMB-5	2024-T3	PMB	22.0	0.1	201,322
2bPMB-5-NF6	Al-2b-PMB-5	2024-T3	PMB	30.0	0.1	47,406
2bPMB-5-NF7	Al-2b-PMB-5	2024-T3	PMB	30.0	0.1	66,209
2bsand-4-NF1	Al-2b-SAND-4	2024-T3	Hand Sanded	22.0	0.1	282,313
2bsand-4-NF2	Al-2b-SAND-4	2024-T3	Hand Sanded	30.0	0.1	90,285
2bsand-4-NF3	Al-2b-SAND-4	2024-T3	Hand Sanded	22.0	0.1	254,557
2bsand-4-NF4	Al-2b-SAND-4	2024-T3	Hand Sanded	30.0	0.1	53,519
2bsand-4-NF5	Al-2b-SAND-4	2024-T3	Hand Sanded	22.0	0.1	199,350
2bsand-4-NF6	Al-2b-SAND-4	2024-T3	Hand Sanded	22.0	0.1	136,094
2bsand-5-NF1	Al-2b-SAND-5	2024-T3	Hand Sanded	30.0	0.1	55,760
2bsand-5-NF2	Al-2b-SAND-5	2024-T3	Hand Sanded	30.0	0.1	60,303
2bsand-5-NF3	Al-2b-SAND-5	2024-T3	Hand Sanded	22.0	0.1	266,035
2bsand-5-NF5	Al-2b-SAND-5	2024-T3	Hand Sanded	22.0	0.1	282,433
2bsand-5-NF6	Al-2b-SAND-5	2024-T3	Hand Sanded	30.0	0.1	48,750
2bsand-5-NF7	Al-2b-SAND-5	2024-T3	Hand Sanded	30.0	0.1	58,035

7075 Smooth Fatigue Data

Specimen ID	Panel ID	Sheet Alloy	Stripping Type	Max Stress (ksi)	Cycles to Failure
7bB1-N0-F1	Al-7b-BASELINE-1	7075-T6	NONE	38	10,000,000
7bB1-N0-F2	Al-7b-BASELINE-1	7075-T6	NONE	45	53,975
7bB1-N0-F4	Al-7b-BASELINE-1	7075-T6	NONE	55	44,013
7bB1-N0-F5	Al-7b-BASELINE-1	7075-T6	NONE	46	42,010
7bB1-N0-F7	Al-7b-BASELINE-1	7075-T6	NONE	44	65,821
7bB1-N0-F8	Al-7b-BASELINE-1	7075-T6	NONE	44	46,533
7bB1-N0-F12	Al-7b-BASELINE-1	7075-T6	NONE	55	30,477
7bB1-N0-F10	Al-7b-BASELINE-1	7075-T6	NONE	48	74,576
7bB2-N0-F8	Al-7b-BASELINE-2	7075-T6	NONE	55	42,643
7bB2-N0-F1	Al-7b-BASELINE-2	7075-T6	NONE	40	128,667
7bB2-N0-F3	Al-7b-BASELINE-2	7075-T6	NONE	55	29,921
7bB2-N0-F5	Al-7b-BASELINE-2	7075-T6	NONE	44	101,815
7bB2-N0-F6	Al-7b-BASELINE-2	7075-T6	NONE	37	852,749
7bB2-N0-F7	Al-7b-BASELINE-2	7075-T6	NONE	44	135,276
7bB2-N0-F11	Al-7b-BASELINE-2	7075-T6	NONE	38	1,334,761
7bB2-N0-F12	Al-7b-BASELINE-2	7075-T6	NONE	44	120,073

Specimen ID	Panel ID	Sheet Alloy	Stripping Type	Max Stress (ksi)	Cycles to Failure
7bBK4-B4-F2	Al-7b-BAKED-4	7075-T6	NONE	38	10,000,000
7bBK4-B4-F5	Al-7b-BAKED-4	7075-T6	NONE	44	201,395
7bBK4-B4-F7	Al-7b-BAKED-4	7075-T6	NONE	55	31,077
7bBK4-B4-F9	Al-7b-BAKED-4	7075-T6	NONE	44	45,553
7bBK4-B4-F10	Al-7b-BAKED-4	7075-T6	NONE	55	24,488
7bBK4-B4-F11	Al-7b-BAKED-4	7075-T6	NONE	40	10,000,000
7bBK4-B4-F12	Al-7b-BAKED-4	7075-T6	NONE	44	172,450
7bBK5-B5-F1	Al-7b-BAKED-5	7075-T6	NONE	55	14,849
7bBK5-B5-F3	Al-7b-BAKED-5	7075-T6	NONE	42	246,746
7bBK5-B5-F4	Al-7b-BAKED-5	7075-T6	NONE	44	33,400
7bBK5-B5-F5	Al-7b-BAKED-5	7075-T6	NONE	55	17,376
7bBK5-B5-F8	Al-7b-BAKED-5	7075-T6	NONE	44	139,060
7bBK5-B5-F10	Al-7b-BAKED-5	7075-T6	NONE	44	10,000,000
7bBK5-B5-F11	Al-7b-BAKED-5	7075-T6	NONE	55	26,090

Specimen ID	Panel ID	Sheet Alloy	Stripping Type	Max Stress (ksi)	Cycles to Failure
7b55-L4-F2	Al-7b-STD-5	7075-T6	LASER	46	50,963
7b55-L4-F5	Al-7b-STD-5	7075-T6	LASER	44	157,941
7b55-L4-F7	Al-7b-STD-5	7075-T6	LASER	55	28,550
7b55-L4-F9	Al-7b-STD-5	7075-T6	LASER	44	117,776
7b55-L4-F10	Al-7b-STD-5	7075-T6	LASER	44	243,037
7b55-L4-F11	Al-7b-STD-5	7075-T6	LASER	55	31,631
7b56-L4-F1	Al-7b-STD-6	7075-T6	LASER	44	93,110
7b56-L4-F2	Al-7b-STD-6	7075-T6	LASER	55	24,529
7b56-L4-F4	Al-7b-STD-6	7075-T6	LASER	55	43,518
7b56-L4-F9	Al-7b-STD-6	7075-T6	LASER	44	57,183
7b56-L4-F11	Al-7b-STD-6	7075-T6	LASER	55	33,879
7bC2-C1-F1	Al-7b-CHEM-2	7075-T6	CHEM	55	29,974
7bC2-C1-F2	Al-7b-CHEM-2	7075-T6	CHEM	44	74,195
7bC2-C1-F4	Al-7b-CHEM-2	7075-T6	CHEM	55	40,058
7bC2-C1-F5	Al-7b-CHEM-2	7075-T6	CHEM	44	79,858
7bC2-C1-F7	Al-7b-CHEM-2	7075-T6	CHEM	44	54,077
7bC2-C1-F8	Al-7b-CHEM-2	7075-T6	CHEM	55	30,053
7bC2-C1-F9	Al-7b-CHEM-2	7075-T6	CHEM	44	50,445
7bC2-C1-F10	Al-7b-CHEM-2	7075-T6	CHEM	55	26,847
7bC2-C1-F12	Al-7b-CHEM-2	7075-T6	CHEM	55	29,667
7bC2-C1-F13	Al-7b-CHEM-2	7075-T6	CHEM	44	65,083
7bCH5-C4-F2	Al-7b-CHEM-4	7075-T6	CHEM	44	41,152
7bCH5-C4-F3	Al-7b-CHEM-4	7075-T6	CHEM	55	9,695
7bCH5-C4-F4	Al-7b-CHEM-4	7075-T6	CHEM	44	25,574
7bCH5-C4-F6	Al-7b-CHEM-4	7075-T6	CHEM	55	8,017
7bCH5-C4-F7	Al-7b-CHEM-4	7075-T6	CHEM	55	7,301
7bCH5-C4-F8	Al-7b-CHEM-4	7075-T6	CHEM	55	12,567
7bCH5-C4-F9	Al-7b-CHEM-4	7075-T6	CHEM	44	20,413
7bCH5-C4-F10	Al-7b-CHEM-4	7075-T6	CHEM	55	16,794
7bCH5-C4-F11	Al-7b-CHEM-4	7075-T6	CHEM	44	37,947
7bCH5-C4-F12	Al-7b-CHEM-4	7075-T6	CHEM	44	24,942
7bPMB-4-F1	Al-7b-PMB-4	7075-T6	PMB	44	123,113
7bPMB-4-F3	Al-7b-PMB-4	7075-T6	PMB	44	98,926
7bPMB-4-F4	Al-7b-PMB-4	7075-T6	PMB	55	37,156
7bPMB-4-F5	Al-7b-PMB-4	7075-T6	PMB	55	40,148
7bPMB-4-F6	Al-7b-PMB-4	7075-T6	PMB	44	123,302
7bPMB-4-F7	Al-7b-PMB-4	7075-T6	PMB	44	64,089
7bPMB-5-F1	Al-7b-PMB-5	7075-T6	PMB	55	35,448
7bPMB-5-F3	Al-7b-PMB-5	7075-T6	PMB	55	51,906
7bPMB-5-F4	Al-7b-PMB-5	7075-T6	PMB	44	136,365
7bPMB-5-F5	Al-7b-PMB-5	7075-T6	PMB	55	37,582

Specimen ID	Panel ID	Sheet Alloy	Stripping Type	Max Stress (ksi)	Cycles to Failure
7bPMB-5-F6	Al-7b-PMB-5	7075-T6	PMB	44	117,617
7bPMB-5-F7	Al-7b-PMB-5	7075-T6	PMB	55	44,518
7bsand-4-F1	Al-7b-SAND-4	7075-T6	Hand Sanded	55	44,122
7bsand-4-F2	Al-7b-SAND-4	7075-T6	Hand Sanded	44	103,766
7bsand-4-F3	Al-7b-SAND-4	7075-T6	Hand Sanded	55	26,109
7bsand-4-F4	Al-7b-SAND-4	7075-T6	Hand Sanded	44	81,340
7bsand-4-F6	Al-7b-SAND-4	7075-T6	Hand Sanded	44	96,530
7bsand-4-F7	Al-7b-SAND-4	7075-T6	Hand Sanded	55	33,602
7bsand-5-F1	Al-7b-SAND-5	7075-T6	Hand Sanded	55	31,337
7bsand-5-F2	Al-7b-SAND-5	7075-T6	Hand Sanded	44	109,786
7bsand-5-F3	Al-7b-SAND-5	7075-T6	Hand Sanded	44	67,758
7bsand-5-F4	Al-7b-SAND-5	7075-T6	Hand Sanded	55	41,866
7bsand-5-F5	Al-7b-SAND-5	7075-T6	Hand Sanded	55	23,782
7bsand-5-F7	Al-7b-SAND-5	7075-T6	Hand Sanded	44	82,344

7075-T6 Notched Fatigue Data

Specimen ID	Panel ID	Sheet Alloy	Stripping Type	Max Net Stress (ksi)	Cycles to Failure
7bB1-N0-NF1	Al-7b-BASELINE-1	7075-T6	NONE	25.0	894344
7bB1-N0-NF4	Al-7b-BASELINE-1	7075-T6	NONE	22.0	> 693605
7bB1-N0-NF5	Al-7b-BASELINE-1	7075-T6	NONE	28.0	53919
7bB1-N0-NF7	Al-7b-BASELINE-1	7075-T6	NONE	35.0	16123
7bB1-N0-NF8	Al-7b-BASELINE-1	7075-T6	NONE	25.0	748971
7bB1-N0-NF10	Al-7b-BASELINE-1	7075-T6	NONE	25.0	257823
7bB1-N0-NF11	Al-7b-BASELINE-1	7075-T6	NONE	35.0	15671
7bB1-N0-NF14	Al-7b-BASELINE-1	7075-T6	NONE	35.0	16303
7bB2-N0-NF1	Al-7b-BASELINE-2	7075-T6	NONE	25.0	345240
7bB2-N0-NF2	Al-7b-BASELINE-2	7075-T6	NONE	21.0	> 527433
7bB2-N0-NF3	Al-7b-BASELINE-2	7075-T6	NONE	25.0	92577
7bB2-N0-NF5	Al-7b-BASELINE-2	7075-T6	NONE	25.0	81832
7bB2-N0-NF7	Al-7b-BASELINE-2	7075-T6	NONE	28.0	59184
7bB2-N0-NF8	Al-7b-BASELINE-2	7075-T6	NONE	35.0	11553
7bB2-N0-NF11	Al-7b-BASELINE-2	7075-T6	NONE	35.0	17964
7bB2-N0-NF12	Al-7b-BASELINE-2	7075-T6	NONE	24.0	10000000

Specimen ID	Panel ID	Sheet Alloy	Stripping Type	Max Net Stress (ksi)	Cycles to Failure
7bBK4-B4-F1	Al-7b-BAKED-4	7075-T6	NONE	35.0	11356
7bBK4-B4-F3	Al-7b-BAKED-4	7075-T6	NONE	26.0	681675
7bBK4-B4-F4	Al-7b-BAKED-4	7075-T6	NONE	35.0	13036
7bBK4-B4-F6	Al-7b-BAKED-4	7075-T6	NONE	25.0	1194282
7bBK4-B4-F9	Al-7b-BAKED-4	7075-T6	NONE	22.0	4464541
7bBK4-B4-F11	Al-7b-BAKED-4	7075-T6	NONE	25.0	221068
7bBK4-B4-F13	Al-7b-BAKED-4	7075-T6	NONE	25.0	91738
7bBK4-B4-F14	Al-7b-BAKED-4	7075-T6	NONE	35.0	15525
7bBK5-B4-F4	Al-7b-BAKED-5	7075-T6	NONE	25.0	242941
7bBK5-B4-F5	Al-7b-BAKED-5	7075-T6	NONE	35.0	17195
7bBK5-B4-F8	Al-7b-BAKED-5	7075-T6	NONE	32.0	27809
7bBK5-B4-F10	Al-7b-BAKED-5	7075-T6	NONE	35.0	10587
7bBK5-B4-F11	Al-7b-BAKED-5	7075-T6	NONE	25.0	7086181

Specimen ID	Panel ID	Sheet Alloy	Stripping Type	Max Net Stress (ksi)	Cycles to Failure
7bS5-L4-NF3	Al-7b-STD-5	7075-T6	Laser	35.0	14625
7bS5-L4-NF4	Al-7b-STD-5	7075-T6	Laser	25.0	141192
7bS5-L4-NF6	Al-7b-STD-5	7075-T6	Laser	35.0	12166
7bS5-L4-NF9	Al-7b-STD-5	7075-T6	Laser	35.0	14907
7bS5-L4-NF12	Al-7b-STD-5	7075-T6	Laser	25.0	3156093
7bS6-L4-NF1	Al-7b-STD-6	7075-T6	Laser	25.0	391002
7bS6-L4-NF4	Al-7b-STD-6	7075-T6	Laser	25.0	74787
7bS6-L4-NF7	Al-7b-STD-6	7075-T6	Laser	35.0	15324
7bS6-L4-NF9	Al-7b-STD-6	7075-T6	Laser	35.0	14671
7bS6-L4-NF10	Al-7b-STD-6	7075-T6	Laser	25.0	322085
7bC2-C1-NF1	Al-7b-CHEM-2	7075-T6	CHEM	35.0	14172
7bC2-C1-NF2	Al-7b-CHEM-2	7075-T6	CHEM	35.0	17385
7bC2-C1-NF3	Al-7b-CHEM-2	7075-T6	CHEM	25.0	159263
7bC2-C1-NF4	Al-7b-CHEM-2	7075-T6	CHEM	35.0	14546
7bC2-C1-NF6	Al-7b-CHEM-2	7075-T6	CHEM	25.0	46415
7bC2-C1-NF9	Al-7b-CHEM-2	7075-T6	CHEM	25.0	62960
7bC2-C1-NF11	Al-7b-CHEM-2	7075-T6	CHEM	25.0	647447
7bC2-C1-NF12	Al-7b-CHEM-2	7075-T6	CHEM	35.0	14579
7bC2-C1-NF13	Al-7b-CHEM-3	7075-T7	CHEM	35.0	13781
7bC2-C1-NF14	Al-7b-CHEM-4	7075-T8	CHEM	25.0	6344707
7bCH5-C4-NF1	Al-7b-CHEM-4	7075-T6	CHEM	35.0	20724
7bCH5-C4-NF2	Al-7b-CHEM-4	7075-T6	CHEM	25.0	104597
7bCH5-C4-NF3	Al-7b-CHEM-4	7075-T6	CHEM	25.0	72774
7bCH5-C4-NF4	Al-7b-CHEM-4	7075-T6	CHEM	35.0	15654
7bCH5-C4-NF6	Al-7b-CHEM-4	7075-T6	CHEM	25.0	113376
7bCH5-C4-NF7	Al-7b-CHEM-4	7075-T6	CHEM	35.0	19580
7bCH5-C4-NF8	Al-7b-CHEM-4	7075-T6	CHEM	25.0	163809
7bCH5-C4-NF9	Al-7b-CHEM-4	7075-T6	CHEM	35.0	28643
7bCH5-C4-NF10	Al-7b-CHEM-4	7075-T6	CHEM	35.0	17222
7bCH5-C4-NF12	Al-7b-CHEM-4	7075-T8	CHEM	25.0	65512
7bPMB-4-NF1	Al-7b-PMB-4	7075-T6	PMB	35.0	18429
7bPMB-4-NF2	Al-7b-PMB-4	7075-T6	PMB	25.0	59363
7bPMB-4-NF3	Al-7b-PMB-4	7075-T6	PMB	25.0	103876
7bPMB-4-NF4	Al-7b-PMB-4	7075-T6	PMB	35.0	14071
7bPMB-4-NF6	Al-7b-PMB-4	7075-T6	PMB	25.0	60064
7bPMB-4-NF7	Al-7b-PMB-4	7075-T6	PMB	35.0	16179
7bPMB-5-NF1	Al-7b-PMB-5	7075-T6	PMB	35.0	15479
7bPMB-5-NF2	Al-7b-PMB-5	7075-T6	PMB	25.0	69195
7bPMB-5-NF3	Al-7b-PMB-5	7075-T6	PMB	35.0	15858
7bPMB-5-NF4	Al-7b-PMB-5	7075-T6	PMB	25.0	73568
7bPMB-5-NF6	Al-7b-PMB-5	7075-T7	PMB	35.0	12973
7bPMB-5-NF7	Al-7b-PMB-5	7075-T8	PMB	25.0	93574
7bsand-4-NF1	Al-7b-SAND-4	7075-T6	Hand Sanded	25.0	69936
7bsand-4-NF2	Al-7b-SAND-4	7075-T6	Hand Sanded	35.0	16506
7bsand-4-NF3	Al-7b-SAND-4	7075-T6	Hand Sanded	35.0	16388

Specimen ID	Panel ID	Sheet Alloy	Stripping Type	Max Net Stress (ksi)	Cycles to Failure
7bsand-4-NF4	Al-7b-SAND-4	7075-T6	Hand Sanded	25.0	65513
7bsand-4-NF5	Al-7b-SAND-4	7075-T6	Hand Sanded	25.0	63626
7bsand-4-NF6	Al-7b-SAND-4	7075-T6	Hand Sanded	35.0	9795
7bsand-5-NF1	Al-7b-SAND-5	7075-T6	Hand Sanded	35.0	12343
7bsand-5-NF3	Al-7b-SAND-5	7075-T6	Hand Sanded	25.0	49476
7bsand-5-NF4	Al-7b-SAND-5	7075-T6	Hand Sanded	35.0	17783
7bsand-5-NF5	Al-7b-SAND-5	7075-T6	Hand Sanded	25.0	58934
7bsand-5-NF6	Al-7b-SAND-5	7075-T6	Hand Sanded	35.0	19489
7bsand-5-NF7	Al-7b-SAND-5	7075-T8	Hand Sanded	35.0	26603